Guidance for the inventory, identification and substitution of Hexabromocyclododecane (HBCD)

Draft
April, 2015

Disclaimer

The designations employed and the presentations in this guidance document are possible options, based on expert judgment, for the purpose of providing assistance to parties in undertaking inventories of hexabromocyclododecane, in its identification and substitution, in order to develop, revise and update national implementation plans under the Stockholm Convention. The Stockholm Convention Secretariat, UNEP or contributory organizations or individuals cannot be liable for misuse of the information contained in it.

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Abbreviations and acronyms

ABS	acrylonitrile-butadiene-styrene
ASR	automotive shredder residue
BAT/BEP	best available technologies/best environmental practices
BFR	brominated flame retardant
c-PentaBDE	commercial pentabromodiphenylether (tetraBDE and pentaBDE)
c-OctaBDE	commercial octabromodiphenyl ether (hexaBDE and heptaBDE)
COP	Conference of Parties
CRT	cathode ray tube
DecaBDE	decabromodiphenyl ether
DSI	detailed site investigation
EEE	electrical and electronic equipment
ELV	end-of-life vehicle
EPS	expanded polystyrene
ESM	environmentally sound management
EU	European Union
GC/MS	gas chromatography/mass spectrometry
HBB	hexabromobiphenyl
HBCD	hexabromocyclododecane
HIPS	high impact polystyrene
HS	Harmonized Commodity Description and Coding Systems
LCD	liquid crystal display
LOI	limiting oxygen index
MCV	maximum concentration value
MFA	material flow analysis
NGOs	non-governmental organization
NIP	national implementation plan
IT	information technology
PBB	polybrominated biphenyl
PBDD	polybrominated dibenzo-p-dioxins
PBDE	polybrominated diphenyl ether
PBDF	polybrominated dibenzofurans
PC	personal computer
PCB	polychlorinated biphenyl
PCP	pentachlorophenol
POPs	persistent organic pollutants
POP-PBDEs	persistent organic pollutants-polybrominated diphenyl ethers
PSI	preliminary site investigation
PWB	printed wiring/circuit board
SC	Stockholm Convention
SCCP	short chain chlorinated paraffins
SFA	substance flow analysis
TV	television
WEEE	waste electrical and electronic equipment
XRF	X-ray fluorescence
XPS	extruded polystyrene

1. Introduction

1.1. Hexabromocyclododecane (HBCD) in the Convention

In May 2013, the Conference of the Parties amended the Stockholm Convention on persistent organic pollutants (POPs) to add hexabromocyclododecane (HBCD) to Annex A, with specific exemption (decision SC-6/13; United Nations 2013). Pursuant to paragraph 4 of Article 21 of the Convention, the amendment was communicated by the depositary to all Parties and on 26 November 2014, one year after notification, the amendment listing HBCD in Annex A to the Stockholm Convention entered into force for most parties[1].

Like all POPs, this chemical possesses toxic properties, resists degradation, and bioaccumulates. It is transported through air, water and migratory species, across international boundaries and deposited far from their place of release, where it accumulates in terrestrial and aquatic ecosystems.

Parties to the Convention for which the amendments have entered into force have to meet the obligations under the Convention leading to the elimination of HBCD for the production and uses not exempted. Each Party that has registered for the exemption pursuant to Article 4 for the production and use of HBCD for expanded polystyrene and extruded polystyrene in buildings shall take necessary measures to ensure that expanded polystyrene and extruded polystyrene containing HBCD can be easily identified by labelling or other means throughout its life cycle.

1.2. Purpose of the guidance

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, will address obligations arising from amendments to the Convention to list new chemicals, in accordance with decision SC-1/12 of the COP.

Under Article 15 of the Stockholm Convention, Parties are required shall report to the Conferences of Parties on the measures it has taken to implement the provisions of this Convention and on the effectiveness of such measures in meeting the objectives of the Convention.

To develop effective strategies that can lead to the elimination of the HBCD and of environmentally sound management of waste containing HBCD, Parties need to acquire a sound understanding of their national situation concerning this chemical. Such information can be obtained through an inventory of HBCD and materials containing HBCD. The establishment of inventories is thus one of the main phases in the development of NIPs and is recommended as part of the elaborated process for reviewing and updating of NIPs, endorsed by the COP (decision SC-2/7).

For complying with the reporting requirements under Article 15 a range of information needs to be gathered, therefore the information compiled in the inventory plays an important role as information basis.

The main purpose of this document is to provide guidance to Parties of the Convention on the establishment of inventories of the HBCD listed under the Convention in 2013. This document will be of use to national focal

[1] 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. Also, 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 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.

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 HBCD.

A robust POP inventory is also a base for an appropriate environmentally sound management of the stockpiles and wastes containing HBCD. Within the Basel Convention a *Draft Technical guidelines for the environmentally sound management of wastes consisting of, containing or contaminated with commercial octabromodiphenyl ether (hexabromodiphenyl ether and heptabromodiphenyl ether), commercial pentabromodiphenyl ether (tetrabromodiphenyl ether and pentabromodiphenyl ether) and hexabromocyclododecane* has been developed (Secretariat of the Basel Convention 2014).

This guidance also contains information on alternatives to HBCD (Chapter 9) which could support the phase out of HBCD. More information on alternatives and alternative assessment is compiled in the publication "POPs in Articles and Phasing-Out Opportunities" (http://poppub.bcrc.cn/)

1.3. Objectives of the inventory

The main objective of the inventory is to obtain information needed for the implementation of their obligations in the Stockholm Convention. More specifically, the objectives are to:

- Provide the basis for development of a strategy in the NIP (i.e. identify the economic sectors that should be prioritized and the type of actions required for those sectors).
- Report to the Stockholm Convention COP on progress made to eliminate HBCD.
- Identify areas where financial or technical support are needed (when resources are limited, to fill the gaps in the inventory/fulfil the obligations of the Convention).

The information obtained about HBCD through the inventory includes the following:

- Past and current uses/production of HBCD at the national level;
- Presence of products and articles containing HBCD on the consumer market;
- Flows (import/export) into a country of products and articles containing HBCD;
- Disposal practices for products and articles containing HBCD when they become wastes;
- Any chemical stockpiles;
- Import/export of HBCD waste; (see Secretariat of the Basel Convention 2014);
- Existence of alternative flame retardants to HBCD;
- Potential contaminated sites.

Information collected on the above will provide broader understanding of the sources of HBCD, the scope of their impact and the risks that they pose to human health and the environment in a country. The information is important for Parties to evaluate whether they comply with obligations under the Convention regarding HBCD and identify areas where they need to develop effective strategies and action plans for managing this POP and in order to meet the obligations. Information collected as part of the inventory will also provide a valuable basis for Parties to report to the COP on measures taken to implement the provisions of the Convention and the effectiveness of such measures (report under Article 15).

The inventory process is usually iterative. In establishing the inventory of HBCD for the first time, Parties will also identify resources and technical capacity needed to further improve the accuracy of the inventory.

1.4. Structure of the guidance

The guidance is divided into seven chapters.

Chapter 1 outlines the purpose of the guidance and the major objectives for undertaking an inventory.

Chapter 2 provides necessary background information on the HBCD for undertaking the inventory.

Chapter 3 outlines the five main steps involved in conducting a general inventory of HBCD. 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 HBCD production and import of HBCD.

Chapters 5 and 6 contain specific guidance for the two main sectors of concern for the inventory of HBCD: polystyrene foam insulation in the building/construction industry, packaging and other uses (chapter 5) and for application on textiles for different uses (chapter 6). These are the sectors in which HBCD have been predominantly used[2] and that are likely to be relevant for many countries.

Chapter 7 provides information on minor applications of HBCD that may be relevant for certain countries and give some guidance on possible inventory approach.

Chapter 8 provides guidance on developing an inventory of potentially HBCD contaminated sites and hot spots.

Chapter 9 is giving initial background information on alternatives for HBCD use and some further considerations.

Annex A provides some guidance on sampling, screening and analysis of materials for the presence of HBCD. Further information can be found in the *Draft Guidance on Sampling, Screening and Analysis of Persistent Organic Pollutants in Products and Articles* (Secretariat of the Stockholm Convention 2013).

Annex B contains sample questionnaires for the major uses of HBCD in EPS/XPS (Annex B1 and for textiles (Annex B2) which can be used for gathering inventory information for these major (former) uses of HBCD.

The key design and content features of this guidance are:

Step by step approach: The guidance is designed to provide a clear 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 (also see chapter 3). The tiered approach provides the opportunity to countries with different capacities to develop an inventory according their realities. More detailed and specific guidance on stakeholders, data collection and others for key sectors can be found in chapters 5 to 7.

Questionnaires and reporting format: Additional information, such as the listing of POP-PBDEs, questionnaire, quality guidelines, is provided in Annexes B1 and B2.

[2] While the use in polystyrene is considerably higher compared to textiles (see chapter 2) the release and exposure from textiles is also relevant and was even considered higher in Europe (Swedish Chemical Agency 2006).

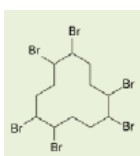
2. Background information on HBCD

2.1. Description of Characteristics of HBCD

Hexabromocyclododecane (HBCD) has a cycle ring structure with Br-atoms attached (see Table 2-1). As a commercially available brominated flame retardant, HBCD is lipophilic, with low water solubility and a high affinity to particulate matter. The molecular formula of the compound is $C_{12}H_{18}Br_6$ and its molecular weight is 641 g/mol. For commercial uses, HBCD usually has three stereoisomers, which consists of 70-95 % γ-HBCD and 3-30 % of α- and β-HBCD, while in theory 16 stereoisomers could be formed (Heeb et al. 2005).

Information about HBCD characteristics are shown in Table 2-1.

Table 2-1: Basic information of HBCD (European Commission 2008, ECHA 2009, UNEP 2010a)

Chemical Properties	**Characteristics of Chemical**
Chemical name (IUPAC)	Hexabromocyclododecane
Identification numbers (CAS number, EC number)	CAS No. 25637-99-4, 1,2,5,6,9,10-hexabromocyclododecane (CAS No: 3194-55-6) and its main diastereoisomers: alpha-Hexabromocyclododecane (CAS No: 134237-50-6); beta-hexabromocyclododecane (CAS No: 134237-51-7); and gamma-hexabromocyclododecane (CAS No: 134237-52-8)." EC number: 247-148-4
Molecular Formula and Structure (general) and molecular weight:	C12H18Br6 (641.7 g/mol) 
Names of the major diastereoisomers identified	alpha-hexabromocyclododecane (CAS No 134237-50-6) beta-hexabromocyclododecane (CAS No 134237-51-7) gamma-hexabromocyclododecane (CAS No 134237-52-8)
Trade name:	Cyclododecane, hexabromo; HBCD; Bromkal 73-6CD; Nikkafainon CG 1; Pyroguard F 800; Pyroguard SR 103; Pyroguard SR 103A; Pyrovatex 3887; Great Lakes CD-75P™; Great Lakes CD-75; Great Lakes CD75XF; Great Lakes CD75PC (compacted); Dead Sea Bromine Group Ground FR 1206 I-LM; Dead Sea Bromine Group Standard FR 1206 I-LM; Dead Sea Bromine Group Compacted FR 1206 I-CM.
Density	2.24 g/cm^3 to 2.38 g/cm^3
Auto flammability	Decomposes at >190 °C
Vapour pressure	6.3·10-5 Pa (21 °C)

2.2. Production of HBCD

According to the Bromine Science and Environment Forum, HBCD is produced in the United States of America, Europe, and Asia (BSEF 2010). Total global demand for HBCD increased by 2002 to 21,447 tonnes, and rose again slightly in 2003 to 21,951 tonnes (BSEF 2006) with production of 28,000 tonnes in 2010 and an estimated total production of HBCD at around 31,000 tonnes in 2011. From this about 13,000 tonnes were produced in the EU and the United States, and 18,000 tonnes in China (UNEP/POPS/POPRC.7/19/Add.1, UNEP/POPS/POPRC.8/16/Add.3).

Since HBCD will be phase out in textile due to Convention obligations and alternatives for HBCD are available for EPS and XPS (ECHA 2009; USEPA 2014; Subsport 2013; see Chapter 9) the future production and use volumes might be expected to decrease in future (ECHA 2009).

2.3. Uses of HBCD

HBCD is used as a flame retardant additive to reduce ignition of flammable polymers and textiles in buildings, vehicles or electrical and electronic equipment (EEE). The main uses of HBCD globally are in expanded and extruded polystyrene foam insulation while the use in textile applications and electric and electronic appliances is smaller (UNEP 2010a).

HBCD has been on the world market since the 1960s. The wider use of HBCD in insulation boards started in the 1980s (European Commission 2008).

The main application of HBCD is in polystyrene foam that is used in insulation boards, which are widely used in the building and construction. Insulation boards with HBCD may also be found in transport vehicles, and in road and railway embankments (UNEP 2010a). These polystyrene foams exist in two forms, as expanded polystyrene (EPS) and extruded polystyrene (XPS) foams, with HBCD concentrations ranging from 0.7% to 3.0%. The manufacture of EPS, XPS and HIPS involves polymerisation and extrusion processes where HBCD is added in the process as one of the additives used (ECHA 2009).

HBCD is used in EPS filling in nursing pillows and bean bags used as easy chairs (UNEP 2010a).

The use of HBCD in EPS in packaging material is considered to be small (UNEP 2010a). However, a first screening of EPS including packaging materials in South Korea revealed that also some packaging material was treated with HBCD or contained recycled EPS/XPS (Rani et al. 2014).

It was assumed that HBCD is not used in food packaging according to the technical report developed in the EU (ECHA 2009). However in a first survey of PS food contact materials HBCD was also discovered in ice box and in fish tray (Rani et al. 2014). HBCD was also detected in water buoy at levels which also indicate that they have been made from recycled EPS (Hong et al. 2013).

The second most important application is in polymer dispersion on cotton or cotton mixed with synthetic blends, in the back-coating of textiles where HBCD can be present in concentrations ranging from 2.2 – 4.3% (Kajiwara et al. 2009). Back-coating to textiles is applied by adding a dispersion containing a polymer and HBCD among other additives as a thin coating film (ECHA 2009). Treated textiles is mainly used in upholstery fabrics such as upholstery in residential and commercial furniture and vehicle seating upholstery, draperies and wall coverings, interior textiles (roller blinds) and automobile interior textiles (UNEP 2010a).

A further smaller application of HBCD is in high impact polystyrene (HIPS) which is used in electrical and electronic equipment and appliances at levels ranging from 1 – 7% (ECHA 2008a).

HBCD-containing HIPS is used in electric and electronic appliances, such as in audio visual equipment cabinets, in refrigerator lining as well as in distribution boxes for electrical lines and certain wire and cable applications (UNEP 2010a).

HBCD may also be added to latex binders, adhesives and paints (Albemarle Corporation 2000, Great Lakes Chemical Corporation 2005).

There are regional differences in the use. In the EU the main use was/is in XPS and EPS, and the uses in HIPS and in textiles are each estimated at ca 2% (ECHA 2009). In Japan 80% of the consumption of HBCD was in insulation boards (including tatami mat) and 20% in textiles (Managaki et al. 2009).

Table 2-2: Use patterns of HBCD (ECHA 2009 with additions)

Material	Use/Function	End-products (Examples)
Expanded Polystyrene (EPS)	Insulation	• Construction, insulation boards, (packaging material) • Insulation boards (against cold or warm) of transport vehicles e.g. lorries and caravans • Insulation boards in building constructions e.g. houses walls, cellars and indoor ceilings and "inverted roof" (outdoor) • Insulation boards against frost heaves of road and railway embankments • Packaging material (minor use food packaging)
Extruded Polystyrene (XPS)	Insulation	• Construction, insulation boards • Insulation boards (against cold or warm) of transport vehicles e.g. lorries and caravans • Insulation boards in building constructions e.g. houses walls, cellars and indoor ceilings and "inverted roof" (outdoor) • Insulation boards against frost heaves of road and railway embankments
High Impact Polystyrene (HIPS)	Electrical and electronic parts	• Electric housings for VCR • Electrical and electronic equipment e.g. distribution boxes for electrical lines • Video cassette housings
Polymer dispersion for textiles	Textile coating agent	• Upholstery fabric • Bed mattress ticking • Flat and pile upholstered furniture (residential and commercial furniture) • Upholstery seating in transportation • Automobile interior textiles • Draperies, and wall coverings • Interior textiles e.g. roller blinds

2.4. HBCD stockpiles, recycling and waste flow

Due to the long service-life of products where HBCD has mainly been used, stockpiles and waste management is a potential increasing source of HBCD releases to the environment. Planning for the current stocks in use and appropriate action towards waste streams will be essential in order to eliminate, reduce and control the environmental load of HBCD from waste management activities (see Figure 2-1).

Once buildings containing EPS/XPS insulation are demolished or articles containing HBCD treated textiles (e.g. vehicles, furniture), plastic waste from electronics and others (see Figure 2-1; Table 2.2) are discarded, they become wastes. Also, by-products generated from production of HBCD or use of HBCD in production, such as residues generated from production or use processes. This might also include sludge containing HBCD generated from related waste water treatment and can also become a source of wastes containing HBCD. The levels of HBCD in municipal sewage sludge without the impact of HBCD producing or using industries might be relatively low (Gorga et al. 2013; Xiang et al. 2015).

The major HBCD containing wastes are listed in Table 2-3 and Parties could use this as a reference to build a list of their own. The knowledge of end-of-life pathways is essential to the better understanding of target wastes identification and for appropriate environmentally sound management (ESM) of these wastes. A *Draft technical guideline for the environmentally sound management of wastes consisting of, containing or contaminated with Hexabromocyclododecane* has been developed in the frame of the Basel Convention (Secretariat of the Basel Convention 2014).

Wastes containing HBCD include production wastes, insulation boards, building and renovation wastes, and from other applications such as WEEE plastics, textiles and transport vehicles. Insulation boards form the majority of HBCD containing waste in particular for those countries using insulation for houses. The life span of polystyrene foam in buildings is reported to be 10 to 50 years (ECHA 2009, Plastics Europe 2009, Posner et al. 2010; UNEP 2010a). The use of HBCD in insulation boards and the HBCD built into buildings and constructions is increasing and it is likely that releases from EPS/XPS from waste materials will be more significant in the future; particularly from about 2025 onwards, as increasing number of buildings containing HBCD will be refurbished or demolished. Most of this material might go to landfill or incineration but a share is at least currently recycled (Rani et al. 2014; Hong et al 2013). Such recycling is not allowed according to the Convention (United Nations 2013) and will need to be controlled. One option to recycle the polymer might be the separation of HBCD from the polymer.

Exposure of workers to HBCD has been documented (European Commission 2008; Thomsen et al. 2007). Therefore care need to be taken also in the end-of-life for human exposure. E.g. there will be some releases of HBCD in dust when buildings with flame retarded insulation boards are demolished. In developing countries, electrical and electronic appliances containing HBCD, POP-PBDEs and other toxic substances are often recycled under conditions which results in a release of HBCD and other pollutants to the environment and contamination of the sites with possible exposure to humans (Labunska et al. 2014; Tomko & McDonald 2013). Furthermore dump sites and open burning are a common end-of-life treatment for HBCD-containing articles including electronic waste.

Solid waste containing HBCD may be scrap materials generated during processing or shredding operations with related particulate releases. Particles might be also released through aging and wear of end products, and disposal of products at the end of their service life. Products and materials in landfill sites will be subject to weathering, releasing HBCD particulates or through leaching primarily to soil and sediments, and, to a lesser extent, to water and air (ECHA 2009, Environment Canada 2010; Remberger et al. 2004). For incineration the release of HBCD and by-products such as polybrominated dibenzo-p-dioxins and dibenzofurans (PBDD/PBDF) are low for state of art incinerators while they might be high for other incinerators and open burning (Mark et al. 2015; Takigami et al. 2014; Weber & Kuch 2003).

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. The COP mandated by its decision BC-11/3, to update the general technical guidelines and the preparation or updating of specific technical guidelines with regard to the chemicals listed in Annexes A, B and C to the Stockholm Convention. In this frame a "*Draft technical guidelines for the environmentally sound management of wastes consisting of, containing or contaminated with Hexabromocyclododecane (HBCD)*" was developed and provide guidance for the environmentally sound management (ESM) of related wastes (Secretariat of the Basel Convention, 2014).

For some countries material/substance flow analysis (MFA/SFA) for HBCD and/or other BFRs in materials have been conducted including the assessment of end-of-life (Figure 2.1) which is considered an excellent approach for an overview on the life cycle of materials and chemicals and related inventory efforts and have been applied for HBCD or POP-PBDEs (Babayemi et al. 2012, 2014; Managaki et al. 2009; Morf et al. 2008).

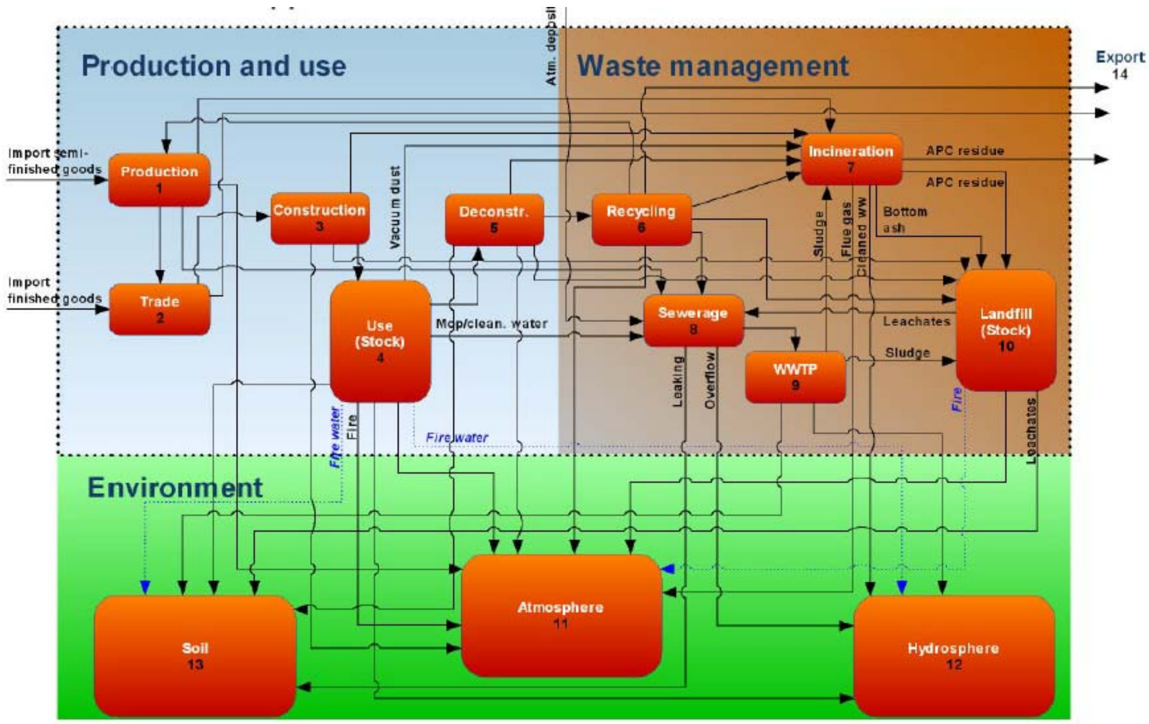


Figure 2- 1: Material and substance flow of HBCD in construction and impacted materials in production/use and waste management and related releases to the environment (Morf et al. 2008)

Table 2- 3: Release and exposure of HBCD and its by-products to the environment in the life cycle

Source	**Released media**	**Examples of waste types**	**Contaminants**
1. HBCD Manufacture			
1.1. Production process	Solid waste, off-gas, waste water	Dusts, products residues, wastewater treatment sludge, waste products, discarded waste filter cloth, wastes from filtration	HBCD
1.2. Products and packaging process	Solid waste (Dust) particles	Waste products, packaging wastes	HBCD
2. HBCD use (Process)			
2.1. Building materials production	Waste gas, waste water and solid waste	Dust, production residue, wastewater sludge, waste products, packaging wastes	HBCD
2.2. Furniture manufacturing	Waste gas, waste water and solid waste	Dust, production residue, wastewater sludge, waste products and packaging wastes	HBCD

Source	Released media	Examples of waste types	Contaminants
2.3. Textile production	Waste gas, waste water and solid waste	Dust, production residue, wastewater sludge, waste products and packaging wastes clothing	HBCD
2.4. Production of High Impact Polystyrene (HIPS)	Waste gas, waste water and solid waste	Dust, waste residue and sludge, waste products and packaging wastes	HBCD
3. Consumer Use			
3.1. Leaching and evaporation from products	Waste gas, waste water and solid waste	Dust/particles, waste residue	HBCD
3.2. Fires	Waste gas, waste water and solid waste	Waste residues, contaminated soil, hot spot	HBCD and PBDD/PBDF
4. Waste recycling and disposal			
4.1. Building material waste recycling	solid waste	HBCD containing EPS and XPS; wastes from recycling or from separation of HBCD from polymer	HBCD and other chemicals
4.2. Waste plastic recycling	solid waste	Waste HIPS, and other plastics Electrical and electronic plastic shells, circuit boards, wire and polyurethane foams which will not be recycled after dismantling	HBCD and other chemicals
4.3. Incineration	Exhaust, Solid Waste, Wastewater	Solid residues (ash, flue gas cleaning residues); Exhaust gas	HBCD and PBDD/PBDF*
4.4. Landfill	Solid waste and Leachate; air releases (fires)	Leachates; fumes from open burning	HBCD and other chemicals; PBDD/PBDF

* The quality of incineration determines the levels of PBDD/PBDF with low levels in state of art incinerators (Mark et al. 2015; Weber & Kuch 2003).

2.5. Potentially HBCD contaminated sites and hot spots

All sites where HBCD have been produced or used, for any of the activities outlined in sections 2.2 to 2.4, could be potentially contaminated with HBCD and for some HBCD productions and also for industries using HBCD such contamination has been documented (Allchin & Morris 2003; Morris et al. 2004; Li et al. 2012, Rüdel et al. 2012; Eljarrat et al. 2005; Eljarrat et al. 2011; Remberger et al. 2004; Sellstroem et al. 1998; Zhang et al. 2013).

Also landfills where HBCD containing wastes have been landfilled can be considered a hot spot sites with related releases in leachates (Remberger et al. 2004).

Users of this guidance document can utilize the information provided in chapters 8 for developing an inventory on potentially HBCD contaminated site (as well as considering information from chapter 3 to 7). The inventory will identify all the sectors involved in the life cycle of HBCD, manufacturing locations and locations of uses and storage, wastes being disposed and methods and locations of waste disposal and treatment. Also examining general and hazardous solid waste practice in their countries will contribute to an inventory of potentially contaminated sites.

3. How to conduct a HBCD inventory

This chapter outlines five broad steps for planning and carrying out a national HBCD inventory. The national focal point of the Stockholm Convention or national project coordinator could be responsible for initiating the inventory process. The existing 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.

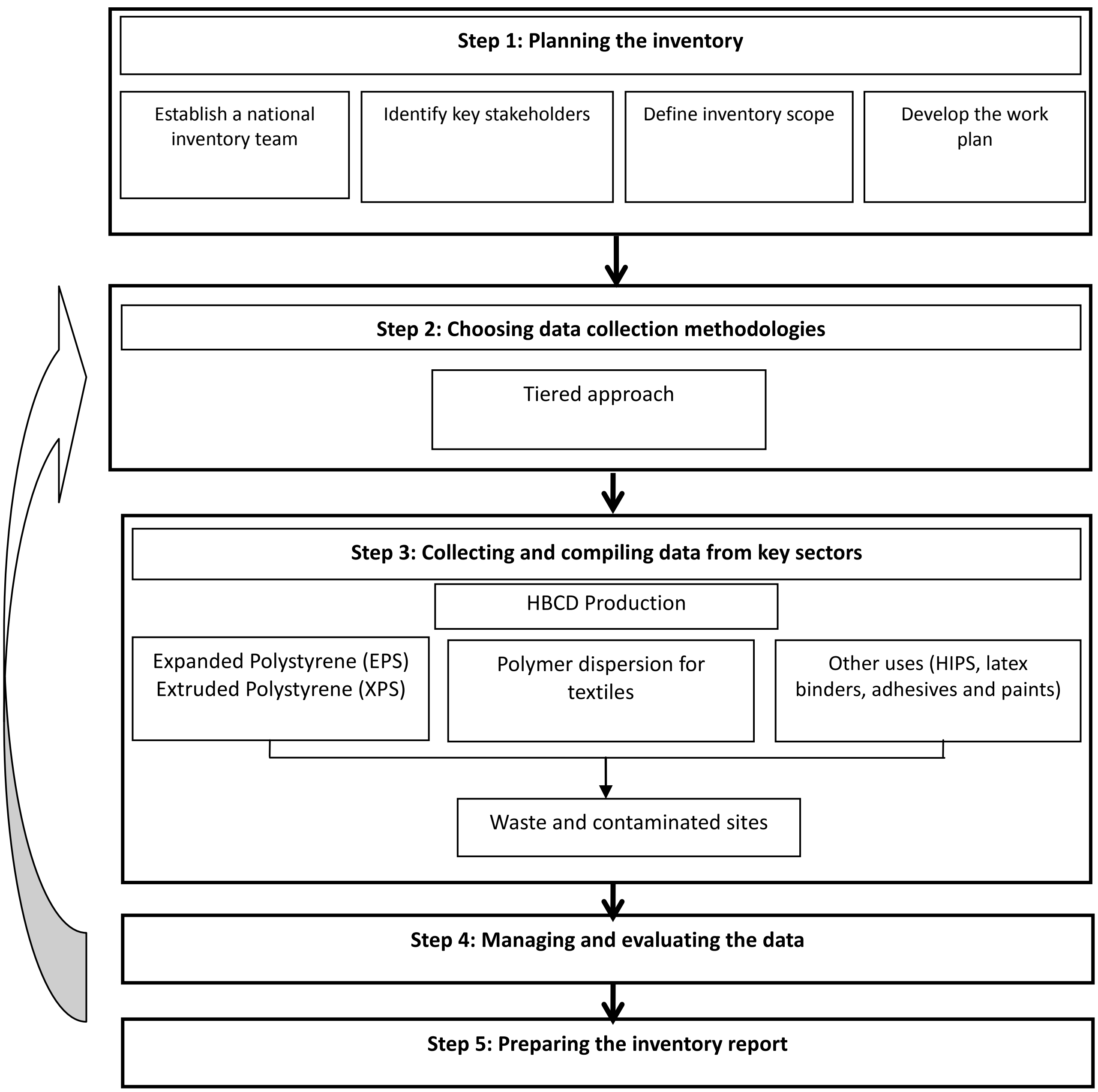


Figure 3-1: Overview of the national HBCD inventory development process.

The inventory process might not 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 a complex monitoring (within tier III) (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 include such activities as an activity within the 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 HBCD. The development of a national inventory of products and articles requires cooperation with the relevant authority in charge of manufacturers of insulation foam, potentially affected consumer products and related suppliers and retailers. Furthermore the customs service, other relevant authorities and organizations might be included as stakeholders. It is important to clearly define the responsibility for developing the inventory. Parties are advised to establish a multi-stakeholder national inventory team for the task.

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. The inventory of HBCD can be combined with the inventory of PBDE since sectors (WEEE plastic, transport sector, construction, furniture and textiles) are basically the same, however with different priorities (see "*Guidance for the Inventory of commercial Pentabromodiphenyl ether (c-PentaBDE), commercial Octabromodiphenyl ether (c-OctaBDE) and Hexabromobiphenyls (HBB) under the Stockholm Convention on Persistent Organic Pollutants*" (Secretariat of the Stockholm Convention 2015). If a PBDE inventory has already been developed selected members of this inventory team with some additional members and stakeholders might compile the HBCD inventory. 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), and academics and researchers from universities and research institutes working on old and new POPs, waste management and possibly material flows, among others (see table 3-1). 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 the new 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 HBCD 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 the recycling sector, and users and owners of articles possibly containing HBCD. Representatives from the key sectors could be included in the inventory team, while others could simply be asked to provide data/information.

Table 3-1: Sectors and stakeholders involved in the use or impact of HBCD

Use	Stakeholders
For all uses	• **Ministry of environment and ministry of industry;** • **Ministry responsible for waste management;** • **Ministry of industry** • **Ministry of Labour** • **NIP coordinator and steering committee;** • **Basel Convention focal point (and stakeholders in Basel);** • **Custom authorities;** • **Authorities in charge with fire safety requirements;**
Expanded Polystyrene (EPS) Extruded Polystyrene (XPS) in construction and buildings and in packaging	• Authorities granting construction permit; • Industry producing EPS an XPS and relate association • Construction industry (in particular related to insulation) • Importers and exporters of HBCD containing articles/products; • Importers and export of HBCD waste; • Retailers of insulation boards; • Former recyclers of HBCD containing articles/products; • NGOs working on waste; NGOs working on POPs; • Other relevant stakeholders in the country.
Polymer dispersion for textiles in treated applications	• Association of importers and exporters of impregnated textiles; • Retailers of impregnated textiles; • University groups working on textile material flows; • NGOs working on POPs; • Other relevant stakeholders in the country.
Other uses (HIPs, latex binders, adhesives and paints)	• Importers and exporters of electric and electronic appliances, adhesives and paints; • Retailers of electric and electronic appliances, adhesives and paints; • Other relevant stakeholder in the country.
Contaminated sites	• Government organizations and impacted district/city • Producers of HBCD; • Manufacturers using or having used HBCD; • University or research institute working on contaminated sites; • Engineering offices specialized in contaminated sites; • Community-based organizations (CBOs) and NGOs; • Labour and trade unions;

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 3-1) and paying special attention to the use categories and life cycle stages discussed in chapter 2. Since the major uses of HBCD (sections 2.3) are polystyrene foam insulation in the building and construction industry, and polymer dispersion for textile back-coating on cotton or cotton mixed with synthetic blends, these two are likely to be the main focuses of the inventory.

Main information includes:

- Past and current production and use of HBCD at the national level;
- HBCD containing articles in use;
- Presence of products and articles containing HBCD on the consumer market;
- Flows (import/export) into a country of products and articles containing HBCD;
- Disposal practices for products and articles containing HBCD when they become wastes;
- Any chemical stockpiles;
- Import/export of HBCD containing waste;
- Alternative flame retardants to HBCD and alternative materials;
- Potentially contaminated sites.

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

- Obligations for HBCD under the Stockholm Convention (see chapter 1);
- Objectives of a HBCD 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 (section 3.2), data collection (section 3.3) and the tiered approaches in chapters 4 to 8, and considering the resources needed for an inventory in relevant national sectors selecting the appropriate tiers for the individual sector. Minor uses (chapter 7) should be considered in the inventory only if information indicates that those uses might be relevant and capacity and resources are available.

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 HBCD inventory is illustrated in figure 3-2. The suggested methodologies for data collection in the three tiers are described in section 3.2.1 and described in each chapter for the individual inventory sectors in the individual. This approach provides flexibility to a wide range of Parties with varying priorities and capacities. 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. Tier I 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 possibly country-specific measurements but should also yield more accurate results.

Parties should endeavour to use methods that provide robust level of certainty, especially when for example the preliminary inventory concludes that HBCD 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 and information gaps. The tier I outputs may be rather qualitative (section 3.2.1) or require (subsequent) verification. The (preliminary) inventory (tier II) focuses on the major sectors and generates (semi)quantitative data. The in-depth inventory (tier III) uses in depth assessment and possibly include analytical measurement methods to obtain precise data on these sectors.

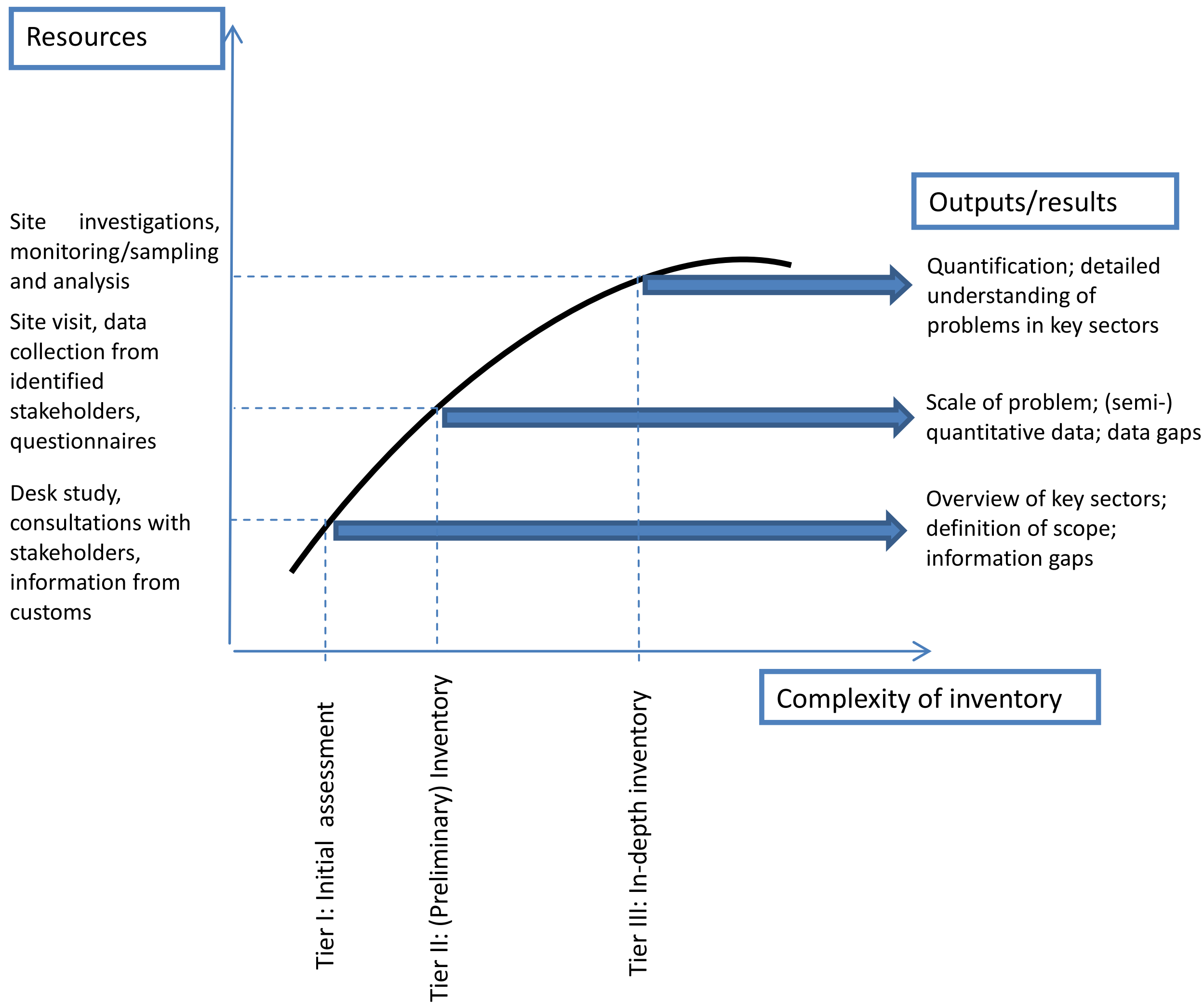


Figure 3-2: The tiered approach to the inventory of HBCD

Tier I: Initial assessment

The initial assessment generally relies on desk studies, interviews etc., i.e. methods that do not require expensive on-site visits or elaborate data collection activities (the team may decide to conduct the interviews on-site). First, the team gets an overview of the former use of HBCD in articles and waste/recycling flows:

- Production of HBCD (section 2.2.);
- Use of HBCD (section 2.3);

- HBCD in waste and recycling (section 2.4);
- Understanding the life cycle of HBCD and potential for emissions (Figure 2-1);

Next, the team collects information about existing past and present national data on the import and use of HBCD and articles containing HBCD from major stakeholders including:

- Ministry of Industry;
- Customs service, the National Bureau of Statistics and the National Central Bank;
- Published literature in scientific journals;
- Technical reports or notes, commissioned research reports and development assistance study reports;
- Desk study and online research;
- Responses to the inquiries and interviews.

The team may have to revisit step 1 to include other relevant stakeholders (or increase number of stakeholders in one category), redefine the scope and refine the work plan before moving on to the next tier.

Tier II: (Preliminary) Inventory

The preliminary inventory generally focuses on specific sectors, as shown in figure 3-2. It involves surveys and site visits to better estimate national data that were identified as missing in the initial assessment/Tier I. Possible applications (Table 2-2) and target locations can be identified, followed by site visits including:

- Current and former production sites of HBCD;
- Waste collection centres and recyclers;
- Waste management facilities;
- End-of-life vehicles treatment facilities;
- Storage and disposal locations of materials containing HBCD.

Tier III: In-depth inventory

The in-depth inventory—may be undertaken if the preliminary inventory concludes that HBCD 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 monitoring using the X-ray fluorescence (XRF) screening and possibly additional measurements with instrumental analysis (see Annex A below and the Guidance on screening POPs in products (Secretariat of the Stockholm Convention 2013). It may also involve detailed inspections of sites mentioned in tier II above and in the inventory chapters below.

3.2.2. Indicative, qualitative and quantitative methodologies

A number of different methodologies can be used for gathering information about HBCD. 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 method**: uses questionnaires to obtain more specific data. Data management is based on estimations from known levels of quantities of HBCD 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. This method is normally used in the initial assessment and preliminary inventory.
- **Quantitative method**: provides accurate and specific numerical information, but needs to be carried out by experts or involve experts in the relevant fields of HBCD and the sectors of investigation. This is an advanced stage of the inventory that includes detailed interviews with industry and possibly site inspection. The quantitative methods might also use sampling and analysis for some areas where the extent of HBCD use is not known (e.g. EPS and XPS packaging). Such investigations might be extensive and labour intensive. If handheld X-ray fluorescence (XRF) equipment is available such investigations might not be costly. Only if chemical analysis (GC/MS or HPLC/MS) is involved such an assessment would become costly. This method is normally used in the 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 production and use of HBCD, and articles containing HBCD. 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 from industry and industry associations, commissioned research reports, and Internet searches. The information should be collated, evaluated and verified if possible, and a gap analysis of the data could be undertaken as well. This approach is typically used in the Tier I assessment (see below).

National sensitizing/inventory workshop on Stockholm Convention and new POPs including HBCD

This national workshop involves major stakeholders from all sectors and groups in which products and articles containing HBCD have been used or are still being used. The national importance of the inventory exercise would be emphasized to participants while also demanding their cooperation and unhindered release of available data in their custody in the national interest. If confidential business information is involved agreements should be reached with respective industries. Breakout sessions and group meetings can be organized during the workshop to ensure that all sectors in which HBCD have been used are adequately covered as well as to get consensus on how best to collect and compile data.

Questionnaire surveys

Questionnaire surveys might be valuable instruments for primary 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. Simple questionnaires could be developed covering questions to gather the information needed to compile data for a Tier II or Tier III assessment (see below).

Questionnaires can be administered through various outreach mechanisms, including electronic distribution, postal distribution; supply chain distribution; distribution via trade unions, NGOs, local governments and community leaders. Questionnaires might also be used for one-on-one interviews or in the frame of a stakeholder workshop.

Site inspection, sampling and analysis

Samples of products and articles can be gathered during in site inspections of relevant storage facilities, recycling locations, and waste disposal/storage facilities.

The screening and analysis of HBCD containing articles and products is described in the *Draft Guidance on Sampling, Screening and Analysis of Persistent Organic Pollutants in Products and Articles (*Secretariat of the Stockholm Convention 2013) and shortly in the Annex A below. An initial screening of HBCD has e.g. been performed in Japan for curtains (Kajiwara et al. 2008, 2009) and textiles in vehicles (Kajiwara et al. 2014). A preliminary monitoring of HBCD in EPS and XPS has been performed in South Korea for packaging (Rani et al. 2014) and for buoy (Hong et al. 2013).

3.3. Step 3: Collecting and compiling data from key sectors

The inventory team needs to investigate if the following exist in the country:

- Production of HBCD;
- Industries currently and formerly using HBCD;
- Products and articles containing HBCD in use;
- HBCD in waste and how is managed;
- Articles containing HBCD that were recycled, the possible extent of recycling, and the types of articles produced from recycling, including the life cycle of HBCD and its potential for emissions;
- Stockpiles and wastes from current and former production and use in industries (countries that produced/produce HBCD or used/use HBCD in industries);
- Sites/locations where activities have occurred that could be potentially contaminated the locations or wider environment with HBCD.

It is desirable to collect and compile the following numerical data in the inventory:

- Quantity of HBCD produced and used in history and quantity which is still produced and used in current newly manufactured products and articles including XPS and EPS in construction (exempted use) and in other non exempted uses (packaging, textile, other uses);
- Quantities of HBCD present in articles and products and articles in EPS and XPS in use in building and construction and possibly in packaging and other uses (e.g. furniture, buoy).
- Quantities of HBCD in use in textiles
- Possibly quantities of HBCD in use in other applications;
- Quantities of HBCD in stockpiles and wastes.

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. Estimations of HBCD quantities in the country for major HBCD former use sectors are provided in chapters 5 and 6. Measurements could be performed by analytical screening on representative samples (see Annex A below and the *Guidance on*

Screening and Analysis of POPs in Articles and Products (Secretariat of the Stockholm Convention 2013)).
The focal sectors to be investigated in the national inventory fall under five key areas:

- HBCD production and import (chapter 4);
- Building and construction sector (chapter 5);
- Textile sector (chapter 6);
- Minor uses such as in electrical and electronic equipment (EEE), paints, coatings and glue (chapter 7);
- Identification of potential contaminated sites and hot spots (chapter 8).

In addition, data collected for the first three key areas will form the basis for the preliminary inventory of the contaminated sites and hot spots.

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 3.2. 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 judgment, 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 must provide training on how to estimate the amount of HBCD 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 HBCD 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 detailed information on certain applications. 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;
- 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, including the actions needed to fulfil the obligations in the NIP, i.e. elimination of HBCD without specific exemption or recycling of HBCD containing materials. Information on BAT/BEP measures will be needed. Information on the environmentally sound management of HBCD are provided in the *Draft technical guidelines for the environmentally sound management of wastes consisting of, containing or contaminated with hexabromocyclododecane* (Secretariat of the Basel Convention 2014).

The inventory might 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 HBCD inventory report. This report will include the inventories of all sectors investigated by the country (see chapters 4, 5, 6, and 7), but also information on potential contaminated sites and hot spots (chapter 8) 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 HBCD to meet the obligations under the Convention.
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 judgment;
- 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. Production and import/export of HBCD

4.1. Production of HBCD

Parties to the Stockholm Convention shall prohibit and/or eliminate the production of HBCD, except if they have notified the Secretariat of their intention to use for the time-limited specific exemption for production and use of EPS and XPS in buildings, as provided in Annex A of the Convention. In addition, a number of countries might continue production of HBCD for any purpose until their ratification. Information on production of HBCD under the exemption and the status of parties' ratification of amendments can be found on the register for specific exemptions on the website of the Stockholm Convention (www.pops.int).

HBCD was and is possibly still produced only in a few countries (China, Japan, the European Union and United States). Countries where HBCD production take or took place would compile data on current (and historic) production and possibly current stockpiles taking into account how to treat confidential business information.

Also information on the amount of production waste and the historic management and deposition of waste from these productions would be gathered within the inventory.

Considering detected HBCD contamination around HBCD production sites (Li et al. 2012; Morris et al. 2004, Rüdel et al. 2012) during the inventory development also information on contamination at and around production sites and/or associated landfills and surface water would be gathered (see chapter 8 on contaminated sites).

The information to be gathered would include data on current and former production of HBCD and related exports. If available also the uses of the produced HBCD would be compiled. All relevant information would be included in the inventory report and selected information in the NIP.

4.2. Import and Export of HBCD

HBCD is often exported and imported as powder or pellets, as masterbatches, as HBCD containing EPS beads and high impact polystyrene (HIPS) pellets downstream in the production chain for the manufacturing of end-products for further professional use or sales to consumers (UNEP 2010a). Several imports of HBCD as a pure compound or in products have been reported within POPRC assessment: Canada (100-1,000 tonnes), Australia (<100 tonnes), Poland (500 tonnes), Romania (185 tonnes) (UNEP, 2010a).

Information on import of HBCD might be available from custom service or HBCD using industries or related industry associations of HBCD using industries (in particular industries producing polystyrene insulation foam and packaging; textiles and EEE plastic). Here information would be gathered on current imports and on historic imports. When gathering the information on current/historic imports of HBCD also information on the related uses would be asked.

For information from customs, HS codes are normally not specific enough to gather information on a specific chemical or chemical in products in articles in import or export until a chemical is not assigned an individual HS code (Korucu et al. 2014). Therefore HS codes can currently not be utilized for assessing import of HBCD or HBCD containing products or articles. For the pure chemical, CAS numbers and trade names might be used for the search in (see Table 2-1).

The information and detailed data on import and export of HBCD and these HBCD containing materials would be compiled in the inventory report.

The information on the amount of imported HBCD might be compared with inventory data on the use of HBCD by the industry. Care should be taken that no double counting of imported HBCD and the further used HBCD in products manufactured by industries is done in the inventory process.

5. Inventory of HBCD in XPS and EPS

XPS and EPS were the major uses of HBCD in the world market. The use of HBCD in XPS and EPS depends on the application and on the region. In Western Europe approximately 70 % of this EPS is flame retarded while in East Europe about 99% of (Seppälä 2013). Only flame retarded EPS contains HBCD.

5.1. Use of EPS and XPS and related HBCD uses

5.1.1. EPS and XPS in the construction sector

As mentioned above, the major use of HBCD was and is in EPS and XPS in the construction sector. Also insulation foam in buildings is the only use exempted in the Stockholm Convention (United Nations 2013). If HBCD is continued to be used in insulation in construction in a country (after registration for exemption) then the EPS/XPS containing HBCD need to be labelled that it can be clearly identified and separated from other EPS/XPS (considering Annex A, Part VII of the Stockholm Convention).

There are a large variety of uses in the construction sector (Table 5-1). Depending on the flammability standards in a country and production policy all or only some of these materials might be flame retarded. For countries with flammability standards requirements, for all EPS/XPS applications in construction flame retardants are needed (e.g. Germany, Netherland, UK). While e.g. inland only require for wall and ceiling insulation, while ground, frost insulation. In other countries no flame retardant is required (e.g. Sweden, Norway) (Seppäla 2013).

Therefore in a first step of the inventory of the construction sector it should be clarified which specific EPS/XPS application in the country is/has been used (see table 5-1) and in which of these applications HBCD is used or has been used. For these applications then the total historic use of the HBCD treated materials in construction would be compiled and the current stock of HBCD and related XPS/EPS in buildings and constructions calculated (see below). Total volumes of EPS/XPS use might be available from national statistics or from industrial associations and related stakeholders.

HBCD is applied in EPS at a typical loading of 0.5 - 0.7 % by weight and in XPS at a typical loading of 0.8 – 2.5 % in XPS by weight (UNEP 2011). These concentrations can be applied when calculating the HBCD amount from the used insulation foam in the country. For an inventory also the total volume of XPS and EPS in current use would be noted since these are the materials which finally need to be managed.

Table 5-1: EPS and XPS uses in buildings and construction (Secretariat of the Basel Convention 2014)

Type of PS	Uses
EPS	Flame-retarded EPS insulation, including: - Flat roof insulation - Pitched roof insulation - Floor insulation 'slab-on-ground' insulation - Insulated concrete floor systems - Interior wall insulation with gypsum board ('doublage') - Exterior wall insulation or ETICS (External Insulated Composite Systems) - Cavity wall insulation boards - Cavity wall insulation loose fill - Insulated concrete forms (ICF) - Foundation systems and other void forming systems - Load bearing foundation applications

	- Core material for EPS used in sandwich and stressed skin panels (metal and wood fibreboard) - Floor heating systems - Sound insulation in floating floors (to avoid transmission of contact sound) - EPS drainage boards EPS concrete bricks, EPS concrete
EPS	Soil stability foam (for civil engineering use)
EPS	Seismic insulation
EPS	Packaging materials made of PS foams*
EPS	Other molded EPS articles, such as ornaments, decorations, logos, etc.
XPS	Flame-retarded XPS insulation boards: Cold bridge insulation Floors Basement walls and foundations Inverted roofs Ceilings Cavity insulation Composite panels and laminates

* EPS packaging is usually not made of flame retardant EPS unless specifically required or due to logistical reasons.

HBCD containing materials from construction in the waste and recycling flow

The largest use and stock of HBCD is in insulation materials in construction which finally will end up as waste. Therefore, the analysis of end-of-life issues for insulation materials containing HBCD is provided as an example as insulation boards comprise the majority of waste containing HBCD (Figure 2-1). The manner in which a product is handled after use contributes to its environmental and human health impacts. There are multiple end-of-life pathways for insulation products including reuse, recycling, landfilling or incineration.

For insulation materials, the end-of-life usually occurs when the building is altered, demolished, or burned down. During demolition, HBCD may be released in dust (European Commission 2008; Sall 2010). Common demolition techniques include implosion with explosives, use of a crane and wrecking ball, or deconstruction of the structure (European Commission 2008). Construction and demolition debris will increase in (Dajadian & Koch 2014; Monier et al. 2011). The amount of XPS and EPS insulation in this waste is unknown. In Europe, HBCD use in insulation began in the 1980s; with a service life of 30 to 50 years, the volume of waste containing HBCD is expected to increase after 2025, as buildings containing insulation flame retarded with HBCD are refurbished or demolished (Sall 2010). The waste management determines the releases into the environment (Figue 2-1; Table 2-3).

Additionally, in some cases, insulation used on or under the soil may be left in the environment after use. For example, polystyrene insulation may be used under parking decks, rails, roads, or exterior insulation of cellars (European Commission 2008). Insulation used for these purposes often remains in the ground after its intended use is over (European Commission 2008).

Granulated EPS waste is also used to improve the texture of agricultural and horticultural soil (UNEP 2010a). The share of HBCD containing EPS in this (recycling) application has not been reported or assessed.

5.1.2. EPS and XPS in packaging

Other uses of polystyrene foam in packaging generally would not require the use of HBCD or another flame retardant (European Commission 2008). However first screening of XPS and EPS in an Asian country has revealed the use and/or recycling of HBCD containing XPS and EPS (Rani et al. 2014). Also the high share of flame retarded use in Eastern Europe of more than 99 % (European Commission 2008) indicates that EPS/XPS packaging produced in this region might largely contain HBCD also in the EPS/XPS packaging.

Since the use of HBCD in packaging might be different in different regions, in the first step of the inventory it need to be clarified to which extent the packaging materials in a country or region contain HBCD due to logistic reasons (e.g. a formulator in the region only produces HBCD containing XPS and EPS) or due to imports or due to recycling of HBCD containing EPS or XPS into packaging.

5.1.3. XPS and EPS in furniture and nursing pillows

According to country information, HBCD treated XPS and EPS has also been used in furniture and nursing pillows (UNEP 2010a). The extent of this use has not been documented jet. Also it is not clear if all EPS and XPS used in furniture (e.g. child seat) or nursing pillows are flame retarded and if there are regional differences. Such information would be gathered by detailed interviews in the Tier II approach or by monitoring in a Tier III approach (see below).

5.1.4. EPS in disposable drinking cups and plates

EPS is used for disposable cups and dishes. As for packaging, HBCD is normally not used for this application. However since EPS and XPS is recycled also such products might become impacted. Therefore also for these uses the presence of HBCD might be assessed. Such information would however probably need a Tier III approach involving some monitoring and only be done by countries with respective capacity (however already a simple XRF screening might be sufficient for such a screening, see below).

5.1.5. Recycled PS plastic from EPS/XPS recycling

According to the Stockholm Convention provisions the recycling of articles/products containing HBCD is not exempted. However this may happen in case of countries which are not Parties to the Convention or have not ratified the HBCD amendment. A first screening of XPS and EPS in an Asian country has revealed the use and/or recycling of HBCD containing XPS and EPS (Rani et al. 2008). Another study done in an Asian country has shown that expanded polystyrenes buoy, which is abundantly used in aquaculture farms and along the coasts, and the predominant item in beached marine debris, could be a source of HBCD in the marine environment (Hong et al. 2013).

In packaging sector, depending on the presence or absence of HBCD in the packaging the EPS/XPS can be further recycled. If some of the packaging in the country contains HBCD then it could be separated before recycling. Technologies for separation could be simple XRF screening (similar to the approach described for WEEE plastic in the POP-PBDE BAT/BEP guidance (Secretariat of the Stockholm Convention 2014)). In WEEE plastic without specific separation the POP-PBDE are more relevant POPs pollutants compared to HBCD (Waeger et al. 2010). For addressing POP-PBDE in WEEE plastic currently the separation technologies can only separate bromine containing plastic from other plastic which also would address the HBCD containing plastic.

The recycling industry has advanced by developing processes which may recover base plastic and capture the non-desirable waste material and additives. In the example of HBCD containing polystyrene foam, such processes allow the recovery of approximately > 99.5% of used flame-retardant additive (http://www.creacycle.de/en/the-process.html; http://www.synbra.com/en/39/187/raw_materials.aspx).

5.2. Step 1: Planning the inventory of HBCD in EPS/XPS and identifying stakeholders

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

Considering the information above, inventory of HBCD in EPS and XPS is expected to address the following:

- HBCD in current EPS and XPS production for construction, packaging and furniture;
- HBCD containing EPS and XPS in stocks/use in buildings and construction;
- HBCD containing EPS and XPS in use and stocks in packaging, furniture and other uses;
- HBCD in EPS and XPS in recycling and end-of-life.

Appropriate members of the inventory task team need to be selected to conduct the inventory of this sector. Specific stakeholders for the inventory of HBCD are listed in Table 3-1. The core inventory team could be extended as appropriate. 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 (A sample questionnaire for HBCD in EPS and XPS is provided in Annex B1).

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

5.3.1. Tier I: Initial assessment of HCBD in EPS and XPS

The aim of the initial assessment is to find out the possible uses and stockpiles of HBCD in the country. For this information it would be assessed if any inventory data on XPS and EPS use in construction, packaging, furniture and other uses are already available in the country or in the region.

In the first step the inventory team can screen the available literature and information from the institution compiling national statistics, the national central bank, published literature in scientific journals, technical reports or notes from industry and industry associations, commissioned research reports, and internet searches. The information should be collated, evaluated and verified if possible, and a gap analysis of the data could be undertaken as well to feed into Tier II assessment.

In a second step the inventory team could contact major stakeholders to get initial information if XPS and EPS are used in the construction sector. Also the ministries of environment and ministry in charge of industry and/or construction could be contacted and asked for available information.

Countries with very limited resources and capacity might focus on the two major use of HBCD (XPS/EPS in construction and the textile sector see chapter 6) in particular when considering that the use of HBCD in casings of electronics is already covered to some extent by the inventory of POP-PBDEs[3].

In Tier I also a first assessment of recycling activities of EPS and XPS are present in the country (e.g. by internet search or first contact to plastic association or major company).

If reasonable information on the total use of XPS and EPS in the country has been found by the Tier I survey then a preliminary inventory of HBCD in this sector might be done by using the total volume of EPS in construction and the related HBCD content (0.5 to 0.7 %) and the total volume of XPS in construction and the

[3] In WEEE plastic without specific separation, the POP-PBDEs are more relevant POPs pollutants compared to HBCD (Waeger et al. 2010). For addressing POP-PBDE in WEEE plastic currently full scale separation technologies can only separate bromine containing plastic from other plastic (Secretariat of the Stockholm Convention 2014) which also would address the HBCD containing plastic. Developing countries (and most industrial countries) have only limited separation capacity for separating bromine containing WEEE plastic. However if a country has companies separating on different plastic types from WEEE then the HBCD in HIPS plastic could be addressed (see chapter 7).

related HBCD content (0.8 to 2.5 %). In the Tier I approach all EPS and XPS in construction might be considered flame retarded with HBCD for a first conservative estimate. However if information on the share of impacted and non HBCD containing EPS and/or XPS is available then this can be considered in the calculation.

5.3.2. Tier II: (Preliminary)[4] Inventory of HBCD in EPS and XPS

In Tier II assessment detailed quantitative information on the current and overall use of XPS and EPS in the building and construction sector should be collected by gathering detailed information from industries (EPS/XPS industry; construction industry), industry associations, importers, retailers and other stakeholders with information. This would build on the information gathered in the Tier I assessment and the relate gap analysis.

5.3.2.1. Gathering information and calculating the HBCD amount and related volumes of EPS/XPS in construction

The information gathered would include the amount of (potentially) HBCD containing XPS and EPS currently used in new buildings and construction for the respective inventory year and also the total amount of HBCD in current EPS/XPS use/stockpile in buildings and construction (considering that the use of HBCD in EPS and XPS started in the 1970s or 1980s). In the survey therefore detailed information would be needed on the historic use of HBCD in industry. Since the alternative flame retardant in XPS/EPS is only available recently and since production capacity for substituting HBCD has only recently been established all flame retarded foam until 2013 can be considered treated with HBCD.

In the Tier II approach also the availability and use of XPS/EPS using alternative flame retardants and other materials approaches for fire safe insulation with EPS/XPS without flame retardants in construction (see e.g. Babrauskas et al. 2012) or other alternative materials (See chapter 9) is important to be compiled. This information will be also important to decide if an exemption of HBCD use in insulation in construction would be needed and would then be registered. In the in depth discussion with the construction sector this would be evaluated in detail with a possible time frame for HBCD phase out for new constructions considering that the specific exemption is only for 5 years and then the COP will decide based on requests.

With the information on the total amount of EPS and XPS present in construction in the country the total maximum amount of HBCD and volume of materials could be calculated. If information on the share to HBCD and non-HBCD treated EPS and XPS used this calculation could be refined. As mentioned in Tier I, the total amount of HBCD in XPS and EPS can be calculated (see Table 5-3a) by using the total volume of EPS in construction and the related HBCD content (0.5 to 0.7 %) and the total volume of XPS in construction and the related HBCD content (0.8 to 2.5 %).

Table 5-3a: Calculation of the amount of HBCD in EPS/XPS used and present in the construction sector

Total volume of EPS used in the construction sector	HBCD content (%)	Total amount of HBCD in EPS in construction sector
Volume of EPS* newly used in construction in	0.5 to 0.7 %	Volume of EPS* used x 0.5 to 0.7 %

[4] Depending on the quality of information and the uncertainties the inventory developed in Tier II might become a robust inventory with sufficient information for further steps in this sector (action plan development) or the information have large gaps and might nee to be called “preliminary”.

the inventory year ……………….tonnes		= …………….. kg of HBCD
Total volume of EPS* present in construction ……………….tonnes	0.5 to 0.7 %	Volume of EPS* used x 0.5 to 0.7 % = …………….. kg of HBCD
Volume of XPS* in construction	**% of HBCD content**	**Total amount of HBCD in XPS* in construction sector**
Volume of XPS* newly used in construction …………….tonnes	0.8 to 2.5 %	Amount of HBCD in XPS* newly used in construction in the inventory year = …………..…………kg of HBCD
Total volume of XPS* present in construction …………………. Tonnes	0.8 to 2.5 %	Total amount of HBCD in XPS* in construction = …………kg of HBCD

* If only a share of EPS or XPS in construction contain HBCD then only this share would be considered in the calculation of HBCD.

With the information of current share of XPS/EPS in the construction sector using HBCD, the share of using alternative flame retardants and the share of EPS/XPS not treated with flame retardants the current amount of HBCD used in the inventory year can be calculated. In this survey it should be noted if the different EPS/XPS with and without HBCD can be distinguished and in particular how the HBCD containing foam is labelled for future identification and environmentally sound management.

Assessment and inventory of end-of-life management from EPS and XPS

Within Tier II it is also expected that the total volume of waste generated for the respective inventory year is assessed and calculated (see Table 5-3b). Such information might also be available from statistics. Detailed information on the amount of HBCD treated EPS/XPS foam in the end-of-life management would be noted. These would include the amount of EPS/XPS from demolishing and refurbishing buildings as well as waste from new constructions and insulations. Also if companies producing EPS and XPS in the country the related waste would be include in the inventory.

In the detailed evaluation of the EPS/XPS in end-of-life also detailed information on the end-of-life management of HBCD containing XPS and EPS including recycling, reuse, treatment, destruction and disposal of HBCD containing EPS/XPS polymers would be gathered. Since recycling of HBCD containing EPS/XPS is not allowed according the Stockholm Convention listing (United Nations 2013), specific technologies might be needed for material recycling of the polymers.[5] Also this information would be compiled in the inventory.

[5] While recycling of HBCD containing waste is not allowed, there are technologies to separate HBCD and the polymer which might allow recycling of the polymer and appropriate end of life management of HBCD (e.g. http://www.creacycle.de/en/projects/recycling-of-expanded-poly-styrene-eps.html).

For the assessment of EPS/XPS generated in future a rough assessment could be developed within Tier II by considering the current stock of EPS/XPS in buildings and a use of 30 to 50 years taking in account when the EPS/XPS have been applied. For a refined assessment a dynamic substance flow analysis could be developed (see Tier III).

In the discussions with the EPS and XPS producing and applying industries also the initial plan of these industries on managing the HBCD containing EPS/XPS stockpiles in the construction sector for the coming decades can be initially discussed for formulating an activity in the action plan.

Table 5-3b: Calculation of the amount of HBCD in EPS* and XPS* in end-of-life from the construction sector

Total amount of EPS entering the waste stream, in the inventory year	**% of HBCD content**	**Total amount of HBCD in EPS entering into the waste stream in construction sector, in the inventory year**
Amount of EPS going to landfill Amount of EPS going into thermal treatment Amount of EPS going into recycling[5]	0.5 to 0.7 %	Amount of HBCD in EPS going to landfill = ……………..kg of HBCD Amount of HBCD in EPS going into thermal/ treatment = ………………kg of HBCD Amount of HBCD in EPS going into recycling[5] = ……………..kg of HBCD
Total amount of XPS entering the waste stream, in the inventory year	**% of HBCD content**	**Total amount of HBCD in XPS entering into the waste stream in construction sector, in the inventory year**
Amount of XPS going to landfill Amount of XPS going into thermal treatment Amount of XPS going into recycling[5]	0.8 to 2.5 %	Amount of HBCD in XPS going to landfill = ……………..kg of HBCD Amount of HBCD in XPS going into thermal/ treatment = ………………kg of HBCD Amount of HBCD in XPS going into recycling[5] = ……………..kg of HBCD

*If it is not possible to assess EPS and XPS separately then a combined calculation for EPS/XPS might be conducted with a determined average HBCD content.

5.3.2.2. Gathering information and calculating the HBCD amount and related volumes of EPS/XPS in packaging and furniture

Within tier II information on the total volume of EPS and XPS used in packaging and in furniture (and possibly in disposable cups and dishes) would be gathered and compiled with related information on HBCD use and presence (see Table 5-3c). For this information direct interviews or questionnaires would be used to gather information on the use and presence of HBCD in packaging, furniture and disposable cups and dishes with related sectors (EPS/XPS industry, packaging industry, furniture industry and retailers). Since the use of HBCD in packaging is considered minor in most regions only a fraction of these EPS and XPS might contain HBCD. However monitoring revealed the use of HBCD containing EPS and XPS in packaging including food packaging (Rani et al 2014). For the XPS/EPS produced in the country or regions the presence or absence of HBCD can be initially assessed in Tier II by in-depth discussions with the producers and importers of EPS and XPS.

A large amount of EPS and XPS is normally imported with packaged goods. For these materials the assessment by interviews and questionnaires might be difficult and useful results might need some monitoring (see Tier III below). When chemical legislation is updated in respect to HBCD, the use and import of HBCD in EPS/XPS would be restricted for others than those listed in an exemption. Also the national legislation would be assessed and revised to stop package goods containing HBCD to be imported.

Depending on the presence or absence of HBCD in the packaging sector then this EPS/XPS can be further recycled. If some of the packaging in the country contains HBCD then it could be separated before recycling. Technologies for separation could be simple XRF screening (similar to the approach described for WEEE plastic in the POP-PBDE BAT/BEP guidance (Secretariat of the Stockholm Convention 2014)).

Also for EPS/XPS in furniture the presence of HBCD would determine the recyclability[7].

In these surveys also the end-of-life management of EPS and XPS in packaging and furniture would be assessed and documented.

Table 5-3c: Calculation of the HBCD amount in XPS and EPS in packaging in use and entering into the waste stream (a modified table could be used for calculating HBCD in furniture)

Total amount of EPS in packaging, in the inventory year	**HBCD content in packaging (%)****	**Total amount of HBCD in EPS in packaging, in the inventory year**
Amount of EPS in packaging* in use Amount of EPS in packaging* entering the waste stream	To be determined through Tier II or by monitoring activities in Tier III	Amount of EPS in packaging* in use / Amount of EPS in packaging entering the waste stream x Impact factor determined using Tier II or Tier III approaches (% of HBCD in packaging) = ……….. kg of HBCD in use = ……….. kg of HBCD entering waste stream
Total amount of XPS in packaging, in the inventory year	**HBCD content in packaging** (%)**	**Total amount of HBCD in XPS in packaging* in the inventory year**
Amount of XPS in packaging* in use Amount of XPS in packaging* entering the waste stream	To be determined through Tier II or by monitoring activities during Tier III	Amount of XPS in packaging* in use/ Amount of XPS in packaging entering the waste stream x Impact factor determined using Tier II or Tier III approaches (% of HBCD in packaging*) = ……….. kg of HBCD in use = ……….. kg of HBCD entering waste stream

* Or for furniture (this would be a separate calculation)

** This would include the share of HBCD impacted packaging and the average HBCD concentration in these packaging and would be described in the report

5.3.2.3. Gathering information and calculating the HBCD amount and related volumes of EPS/XPS in recycling and related waste

As mentioned above, the recycling of HBCD containing EPS and XPS is not allowed in the Convention (United Nations 2013). Since not all EPS/XPS is treated with HBCD these untreated EPS/XPS can be recycled without restriction. Furthermore the separation of HBCD from EPS/XPS might be possible (see e.g. http://www.creacycle.de/en/the-process.html) and could possibly be used for the recycling of HBCD containing HBCD.

If recycling activities of EPS and XPS are present in the country then further assessment on the extent of EPS and XPS recycling would be performed by interviews with the respective industries and site visits. Here an assessment would be made if HBCD is likely present in recycling (e.g. if EPS/XPS insulation foam from construction is recycled) or if e.g. only EPS/XPS from packaging is recycled which might not contain HBCD depending on the country (see Rani et al. 2014). The companies recycling EPS or XPS might already have measurements or might know the bromine content from screening.

All this information would be compiled in table 5-3d. If from the recycling companies no information on HBCD or bromine content is available then a Tier III assessment with bromine screening or HBCD analysis might be needed to fill table 5-3d (see Tier III below and Annex A below).

Table 5-3d: Calculation of the amount of HBCD present in EPS* and XPS* in recycling and related wastes

EPS materials used in recycling (tonnes)	**HBCD present or absent and content (ppm)**	**Products made from recycling (tonnes)** **Related HBCD content (ppm)**	**Waste generated during recycling (tonnes)** **Related HBCD content (ppm)**
XPS materials used in recyling (tonnes)	**HBCD present or absent and content (ppm)**	**Products made from recycling (tonnes)** **Related HBCD content (ppm)**	**Waste generated during recycling (tonnes)** **Related HBCD content (ppm)**

5.3.3. Tier III: In-depth inventory of HBCD in XPS and EPS

The in-depth inventory can consist of a field survey with detailed assessment of the share of HBCD containing materials in the different applications. This might include the screening of XPS and EPS for bromine or HBCD.

As mentioned above the amount of HBCD use in packaging is not well documented with regional differences and an inventory of this sector might only lead to a reasonable data by involving monitoring approaches. Such a monitoring could be performed by screenings with handheld XRF equipment by screening the bromine content (see e.g. *POP-PBDEs BAT/BEP Guidance*[6] (Secretariat of the Stockholm Convention 2014) and *Draft Guidance on Screening and Analysis of POPs in Articles and Product*). Bromine positive samples of XPS/EPS (packaging and furniture and minor uses) can be considered to contain HBCD since HBCD was up to now the only brominated flame retardant used in EPS and XPS. Handheld XRF equipment has been purchased from a range of developing countries in the frame of the NIP update and therefore also these countries would be able to do a national (or even regional) assessment.

Also not all EPS and XPS applications in buildings and construction might contain HBCD (see above chapter 5.1). Therefore the information gathered in Tier I and Tier II might be validated, confirmed or refined by XRF screening for bromine content of the different applications of EPS and XPS in the construction sector (see Table 5-1). Since currently HBCD is substituted by another brominated flame retardant, the bromine screening of current newly used EPS and XPS in the construction sector might not be sufficient to determine the presence of HBCD. For current used EPS and XPS in construction bromine positive tested samples could either contain HBCD or the alternative bromine containing EPS/XPS system. This would need further clarification with the producer or supplier. According to the convention obligation all HBCD containing EPS/XPS should be labelled which currently might not already be implemented in all cases. However all EPS and XPS which have been produced and used before 2014 and contain bromine are most likely containing HBCD since the alternative only recently entered into the marked in larger scale and can therefore be considered to be flame retarded with HBCD.

In the Tier III screening also sensitive EPS uses such as disposable drinking cups and plates might be screened for their bromine content. Also bromine positive tested samples most probably would contain HBCD and might indicate uncontrolled recycling of HBCD or even use of HBCD treated EPS depending on the bromine content detected. For concentration of 5000 ppm and higher the HBCD most probably stem from intentionally added HBCD, while concentration of less than approx. 3000 ppm might indicate that these products are produced from recycled EPS. Low HBCD content in EPS and PS in sensitive uses has e.g. been detected in the study on EPS and XPS in packaging including food packaging indicating such recycling into sensitive uses (Rani et al. 2014).

The results of XRF screening would be described in the inventory report and shortly in NIP report. After Tier III assessments have been done, the tables 5-3a, 5-3b and 5-3c can be filled or refined (instead of using only the information from Tier II assessment).

Another possible Tier III approach could be the development of a material and substance flow analysis of HBCD containing EPS/XPS (see e.g. Morf et al. 2007, 2008; Managaki et al. 2009). Material and substance flow analysis can support waste management and material recovery. Dynamic material and substance flow analysis can be used to predict the generation of waste volumes in future (see e.g. Morf et al. 2007, 2008).

The inventory development of POP-PBDE in transport sector and in WEEE/EEE plastic in Nigeria from Basel Conventional Regional Center has shown that also developing countries are able to use the material and substance flow analysis approach in the frame of Stockholm Convention inventory development (Babayemi et al. 2012, 2014) using the free software for substance flow analysis from Vienna University (http://www.stan2web.net/). Such or similar approaches could be considered in the development of an

[6] This draft guidance document is under revision in accordance with decision SC-6/10.

in-depth inventory.

5.4. Step 4: Managing and evaluating data

In the data evaluation step the data 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 inadequate, further data collection or screening (Tier III) might be undertaken.

When a country improves the inventory of the EPS/XPS use over time, the data quality will become better and more reliable. Countries (or cities) might establish and update inventories of their buildings and the construction sector for further waste management planning and overall material recovery planning purposes (e.g. for urban mining purpose; Brunner 2011; U.S. General Service Administration, 2015). This could result over time in robust sector inventories of buildings. When developing a comprehensive inventory of buildings also contamination in buildings which need to be considered in the final waste management might be included in such an inventory (in addition to HBCD in insulation this could include POP-PBDEs, PCB in open application (see Wagner et al. 2014) and asbestos).

If buildings HBCD containing XPS/EPS are individually registered then this information could be managed in an appropriate national database (or city level) on contaminant in buildings (together with PCB in open application in buildings or asbestos) for further planning when buildings are demolished or refurbished. Such a database could be valuable for the (waste) management of construction and demolition waste (which will be a major waste flow in future for many countries) and would be made available to governmental body responsible for waste and resource management (ministry of environment, ministry of industry or other responsible ministries) and possibly to the competent authority of the Basel Convention.

5.5. Step 5: Preparing the inventory report

The final information and data for HBCD use and presence in XPS and EPS in the country would be accompanied by the methodology used and the detailed calculations and assumptions done in the calculations as an audit trail in a separate chapter of the HBCD inventory report. All country-specific adjustments and estimates would be noted and described.

To provide an overview on the presence of HBCD at the national level, as well as on the amount of the HBCD impacted volumes of EPS/XPS materials to be managed during the NIP implementation phase, the information which could be included in dedicated NIP paragraphs may include a brief summary on:

- Overall use of EPS and XPS in the building and construction sector and the amount of HBCD in these uses.
- Amount of (potentially) HBCD containing XPS and EPS currently used in new buildings and construction and availability and use of XPS/EPS using alternative flame retardants or other approaches for fire safety insulation in construction.
- Regulation on flammability standards in the country requiring and determining flame retardant use in the building and construction sector.
- Amount of HBCD in current EPS/XPS use/stockpile in buildings and construction (considering that the use of HBCD started in the 1980s and possibly 1970s).
- Estimated amount of HBCD impacted packaging materials.

- End of end-of-life management of HBCD containing XPS and EPS including reuse, recycling[7], treatment, destruction and disposal of HBCD containing EPS/XPS polymers. For compiling this information also consult the related draft Basel Convention guideline (Secretariat of the Basel Convention 2014)

While several of these information can be generated from a Tier I and Tier II inventory, some of the listed information might only be included if a Tier III inventory approach has been used.

Also further activities suggested for assessing and managing the use of HBCD in EPS and XPS would be included in the NIP.

[7] Please note that the recycling of HBCD containing materials is not exempted in the Stockholm Convention.

6. Inventory of HBCD in textiles

The second most important application is in polymer dispersion on cotton or cotton mixed with synthetic blends or synthetic, in the back-coating of textiles (UNEP 2010a). Also the use in textiles was considerable lower than for XPS/EPS the environmental releases of these two applications were similar in Europe (ECHA 2009). Back-coating to textiles is applied by adding a dispersion containing a polymer and HBCD among other additives as a thin coating film (ECHA 2009). The flame retardant can be introduced to the textile by impregnation/spraying or by spinning flame-retarded polymer into textile yarn.

HBCD can be present in flame retarded textiles at concentrations ranging from 2.2 % – 4.3 % (Kajiwara et al. 2009) or even up to 15 % (UNEP 2010a).

The use of HBCD in textile is not listed as exemption. However HBCD might still be used in textiles in countries having not ratified the Stockholm Convention or which have not yet ratified the HBCD amendment and where industry have not yet switched to alternative flame retardants since Parties have not yet set the respective regulatory frame.

Textile applications for HBCD include (European Commission 2008; UNEP 2010a):

- Residential and commercial upholstered furniture;
- Seating and other textile interior in transportation (trains, air planes, ships);
- Automobile interior textiles;
- Wall coverings and draperies;
- Interior textiles e.g. roller blinds and curtains;
- Bed mattress ticking;
- Protective clothing and other technical textiles;
- Tents;
- Other treated textiles.

The different textile applications treated the last approximate 40 years have partly already entered the end-of-life treatment and ended in landfills, incinerators and possibly in recycling. Due to the long lifetime of some of these uses (in transport seating; other automobile application, curtains, tents) a considerable share of these textiles might be still in use.

The application of flame retardants in textiles depends on the flammability standards in the different countries (Horrocks 2013; Shaw et al. 2010). Flammability standards define for which application specific material requirements in respect to ignitability is made which trigger the use of flame retardants and can determine which type of flame retardants are needed. For example the German DIN 4102/Class B1 standard can be fulfilled by the use of HBCD or other brominated flame retardants (Zinser 2009). These standards depend on the respective uses and are different in different countries or regions (Horrocks 2013; Shaw et al. 2010) and some have been triggered by science evidence (Chicago Tribune 2012).

Therefore textile-related fire regulations between different nations may offer an overall confusing picture in terms of the items regulated and the applications covered by them but, in general, regulations fall into one of several categories depending on whether they apply: to a normal consumer living in a domestic environment; a member of the public in a public environment (e.g., hotel, airport, public building (including hospitals and prisons)); in the workplace for worker protection; for personal protection in the emergency and military services and in transport (Horrocks 2013).

Since the total production volume of HBCD has been increased until recently (Secretariat of the Basel Convention 2014) it can be assumed that HBCD has been used until recently in major applications (for EPS and XPS see chapter 2.1 and chapter 5) including textiles and might still be used. Although it has been reported that the share of use in the textile sector has been decreases the last years (UNEP 2010a) still significant volumes could be used in this application in some regions.

Also POP-PBDEs (and DecaBDE currently assessed in the POP Review Committee) have been used in the textiles sector (Secretariat of the Stockholm Convention 2015; Kajiwara et al. 2014). In the POP-PBDE inventory development the textile sector was considered a minor application. If textiles are addressed within the HBCD inventory then also the POP-PBDE could be addressed if this has not been done within the POP-PBDE inventory (see POP-PBDE inventory guidance (Secretariat of the Stockholm Convention 2015)).

6.1. Uses of textiles possibly containing HBCD

6.1.1. HBCD use in textiles in transport seating and other textile/synthetics use in transport sector

Textiles in transport are, in general, associated with seating, floorcoverings, roof-lining fabrics and other furnishings within the vehicle or vessel interior (Horrocks 2013). In most of transport applications in which safety is an issue, there are national or international regulations that govern their fire-safety. Therefore materials which meet a defined required level of flame resistance or materials with flame retardants are used in different textile application in transport including public transport, air planes, ships and cars.

The use of flame retardants in cars have been linked to the levels of PBDEs in human blood serum in a study in the United States (Imm et al. 2009) and also the highest HBCD exposure in United Kingdom via dust were determined to cars (Abdallah & Harrad 2009).

In aircraft, all internal textiles such as seating, internal décor and blankets require defined levels of flame or fire resistance to internationally recognized standard levels. Therefore particular flammability standards exists e.g. for airplanes (e.g. UK Civil and US Federal Aviation Authorities' requirement for fire-resistant seating materials in all passenger aircraft) (Horrocks 2013) with related flame retardant use. In a first monitoring study high levels of flame retardants (including HBCD) were detected in dust in commercial airplanes (Allen et al. 2013).

Also for railways a range of flammability standards on national or regional (e.g. European Directive 2008/57/EC) exist which require fire safety for materials used (Horrocks 2013). Therefore also for this transport sector HBCD (and other flame retardants) have most likely been used in relevant volumes. However there has not been any monitoring of HBCD in trains.

In transport HBCD, PBDEs but also other flame retardants are used for different fabrics. Up to now only one specific screening of HBCD and PBDE in individual textiles of cars has been conducted (in Japan) including HBCD (Kajiwara et al. 2014). In this study HBCD was detected in 50% of the analysed floor covering (n=4) but has not been detected in any of the analysed seat fabric (n=16) but instead PBDE were detected[8] (Kajiwara et al. 2014). HBCD has also been detected in door trim fabrics in this study. The car manufacturer or the year of manufacture of the respective cars was not documented in this monitoring (Kajiwara et al. 2014).

Therefore it is not documented in detail for which textile applications in the transport sector HBCD has been mainly used and e.g. which car manufacturers have used HBCD for which years and if HBCD is still used in this sector.

6.1.2. HBCD use in textile applications used indoor

A range of textile application in residential homes, public buildings (including hospitals and prisons), air ports or hotels are flame retarded. This might include curtains, textile upholstery of furniture, bed mattress ticking, wall coverings and draperies (UNEP 2010a; Horrocks 2013). It has been concluded that indoor contamination with HBCD is a relevant exposure pathway to humans (Harrad et al. 2010b). An assessment of the temperature dependent emission rate of HBCD from a curtain showed measurable releases to air above 80 °C and the human exposure risk was considered small (Miyake et al. 2009). In this study the (long-term) releases of HBCD by the release of fibers and related exposure was however not considered and assessed.

Also for furniture application the national flammability standards (e.g. in the United States an UK) can trigger the use of flame retardants as was revealed for POP-PBDEs (Secretariat of the Stockholm Convention 2015; Shaw et al. 2010, Stapleton et al. 2012). Such national flammability standards most probably also trigger the use of HBCD in such applications.

Only a few studies on HBCD in home textiles have been performed. A preliminary screening of HBCD in curtains in Japan revealed a relevant use of HBCD in this application (Kajiwara et al. 2008, 2009). From 10 curtains tested positive for bromine, 9 curtains contained HBCD in a concentration between 2.2 % to 4.3 %. This revealed the high usage of HBCD in this application for this country or possibly region.

6.1.3. HBCD use in textile clothing

HBCD is also use in textile clothing. In particular specific personal protective equipment (PPE) clothing (e.g. for fire fighter and military uniform; other technical textiles) can contain HBCD or other flame retardants. But also for nightwear clothing in some countries flammability standards exist but also for normal closing in some countries flammability standards exists which require the (e.g. British Standards (BS) 54 Update on Flame Retardant Textiles 5722). These standards do however not necessarily need the use of flame retardants but can be met by fibers with high Limiting Oxygen Index (LOI) (e.g. wool has high resistance to flammability with an LOI of 25 (Adivarekar & Dasarwar 2010). But some children sleepwear might contain flame retardants with associated health risk (Blum & Ames 1977). Also some standards require only the labelling of fire risk for clothing (e.g. in Australia or New Zealand Standards Association of Australia (2003), Australian Government 2007).

Table 6-1: Selected national and international nightwear fire regulations (Horrocks 2013)

Country	Regulation
UK	The Nightdress (Safety) Regulation, Statutory Instrument S.I. 839:1967 and The Nightwear (Safety) Regulations S.I. 2043:1985, HMSO, London, UK.
Netherlands	Netherlands The Nightwear (Safety) Regulations 1985; from 2008 all clothing

[8] More than 60% of the bromine containing seat fibric contained PBDE as flame retardant (5500 to 78000 ppm) but it was not reported to which extent these were POP-PBDEs. In 6 of the 16 seat fibrics HBCD was detected at a concentration between 0.15 to 50 ppm (Kajiwara et al. 2014). These HBCD levels can be considered a secondary contamination (e.g. from related floor covering with up to 13,000 ppm HBCD). Such secondary indoor POP contamination has been well documented for PCBs (Bent et al. 2000).

	must meet minimum burning requirements.
EU	EU General Product Safety Directive (2001/95/EC); European Standard (EN) 14878:2007. Textiles – Burning Behaviour of Children's Nightwear – Specification, 2007.
Unite States	USA Standard for the Flammability of Children's Sleepwear, Title 16, Code of Federal Regulations (CFR), 16 CFR Parts 1615 and 1616 (recodified from Department of Commerce to Consumer Product Safety Commission at 40 FR 59917, 30th December 1975). Standard for the Flammability of Clothing Textiles, 16 CFR 1610, February 2007.
Australia and New Zealand	Australian Government: Trade Practices (Consumer Product Safety Standards) (Children's Nightwear and Paper Patterns for Children's Nightwear) Regulations 2007. Product Safety Standards (Children's Nightwear and Limited Daywear Having Reduced Fire Hazard) Regulations, 2008 (declares AS/NZS 1249:2003 as the standard with variations stated in Amendment A 2008).

6.2. Step 1: Planning the inventory of HBCD in EPS/XPS and identifying stakeholders

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

Considering the information above, inventory of HBCD in textiles is expected to address the following:

- HBCD in textile used in transport sector in current use and in end-of-life;
- HBCD in textile used indoor in current use and in end-of-life;
- HBCD in textile clothing in current use and in end-of-life.

Appropriate members of the inventory task team need to be selected to conduct the inventory of this sector. Specific stakeholders for the inventory of HBCD are listed in Table 3-1. The core inventory team could be extended as appropriate. 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.

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

6.3.1. Tier I: Initial assessment of HCBD in the textile sector

The aim of the initial assessment is to find out the possible uses and stockpiles of HBCD in the country. For this information it would be assessed if any information or inventory data on HBCD use in textiles are already available in the country and in the region.

In the first step the inventory team can screen the available literature and information from national statistic institutions, published literature in scientific journals, technical reports or notes from industry and industry associations, commissioned research reports, and internet searches.

In this step also an initial assessment of flammability standards for different applications in textiles (e.g. transport seating, curtains) would be compiled.

In a second step the inventory team could make first contacts to major stakeholders to inform that HBCD will not be allowed to be used in these applications and in this communication get initial information if HBCD was used or possibly is still used in the textile sector. Also the ministries of environment and ministry in charge of industry could be contacted and asked for available information.

The first compilation of information on the use of HBCD in the textile sector in the country (or region) or information on certain possibly impacted textile applications that has been found present in the country by the Tier I survey could result in a preliminary or robust list of applications and products which might contain or probably contain HBCD I textiles. But this assessment will be rather qualitative. In this stage the information might not be sufficient to do any quantitative estimate on the share of different applications impacted or possibly impacted by HBCD and therefore the amount of HBCD used.

For some application a first rough estimate might be conducted on e.g. the total volume of textiles in the transport sector or textiles from certain protective clothing (fire fighters or military) or specific applications (e.g. curtains) to get the order of volume magnitude of this application. However in Tier II and Tier III further information are needed to estimate the share of HBCD treated products and articles in the respective sector. This assessment on total volume can also lead to a prioritization of efforts in Tier II and possibly Tier III.

The information should be collated, evaluated and verified where possible, and a gap analysis of the information would be undertaken as well to feed into Tier II assessment.

6.3.2. Tier II: (Preliminary)[9] Inventory of HBCD in textile applications

In Tier II assessment semi-quantitative information and for some application possibly quantitative information on the current and historic use of HBCD in the textile sector in the country should be compiled by gathering detailed information from industries producing the products and articles (textile industry; furniture industry, car and other transport industry), from related industry associations, importers, retailers and other stakeholders with related information. This would build on the information gathered in the Tier I assessment and the related gap analysis. Also the Regional Stockholm Convention Center might be contacted for information on HBCD use in the region.

6.3.2.1. Gathering information and calculating the HBCD amount and related volumes of HBCD containing materials in textiles and associated materials in the transport sector

To gather robust information industries producing, importing or using textiles for the different transport (vehicles, trains, air planes and ships) sector would be contacted by direct interviews or by questionnaire survey. This contact could be combined with informing these sectors that HBCD is listed in the Stockholm Convention and will not be allowed to be used in new products as well that the treated textiles will need an appropriate environmentally sound management (Secretariat of the Basel Convention 2014) when the vehicles, trains, air planes or ships will reach their end-of-life or when seats or other textile applications containing HBCD will be refurbished.[10]

Since POP-PBDEs have also been used in this application as minor uses they also can be included in the assessment if they have not been addressed before (see chapter 6 POP-PBDE inventory guidance; Secretariat of the Stockholm Convention 2015). In the screening of upholstery in vehicles, PBDEs have been detected in even higher concentrations compared to HBCD while in the vehicle floorings HBCD were detected at higher levels (Kajiwara et al. 2014).

[9]Depending on the quality of information and the uncertainties the inventory developed in Tier II might become a robust inventory with sufficient information for further steps in this sector (action plan development) or the information have large gaps and might nee to be called "preliminary".
[10] The related Basel Convention draft technical guidance can be given to the stakeholders.

In the discussion or questionnaire approach with the respective industries and authorities flammability standards for the individual transport sector would be gathered. While for some sectors this might be regulated by international law (e.g. air planes and ships) (Herrock et al. 2013) for other transport sector (vehicles like car, trucks and busses as well as trains) it might rather be regulated on national level. The requirements of the respective standards would be assessed in respect to the possible (former) use of HBCD in related textile applications.

In the discussion or questionnaire survey with the individual stakeholders the current and former use of HBCD for the different transport sectors would be clarified as well as the total volume of HBCD currently and historically used in the respective sector. Here also the total volume of textiles which are treated or possibly treated would be noted.

Assessment and inventory of end-of-life management from HBCD containing textiles in transport

Other information which would be gathered is the related end-of-life treatment of textiles treated or possibly treated with HBCD. Here information on the former and current end-of-life treatment (including recycling, reuse, treatment, destruction and disposal of HBCD containing textiles) would be gathered including the volumes of possibly HBCD treated materials. Also it would be clarified if these textiles can be removed from other materials or if e.g. for seats and other upholstery materials the materials cannot be separated or are normally not separated. This would increase the volume of materials which would finally need to be managed in an environmentally sound manner. Since a major application of POP-PBDEs is in the polyurethane foam in transport also here HBCD and POP-PBDE containing waste could be inventoried together (see chapter 5 and 6 of POP-PBDE inventory Guidance). Also polymer wastes from vehicles (entire seat with textile and PUR foam or entire light shredder fraction) would likely contain HBCD and POP-PBDEs (and possibly PCB and PFOS) and here these POPs could be managed together in a synergistic manner (see chapter 6 in the PBDE BAT/BEP guidance (Secretariat of the Stockholm Convention 2014) and the related Basel Convention technical guidance (Secretariat of the Basel Convention 2014a,b). Here also detailed information on the end-of-life treatment of fractions containing or possibly containing HBCD would be gathered. This would include the information on the amount of materials currently recycled, landfilled or treated in incinerators or cement kilns or by other means. In Tier II at least a rough estimate of the share of individual end-of-life treatments could be done, similarly as e.g. was done Nigeria for the assessment for their POP-PBDE containing polymers in the transport sector (Babayemi et al. 2012).

In the discussions with the respective HBCD using and applying textile industries also the initial plan of these industries on managing the HBCD containing EPS/XPS stockpiles in the construction sector for the coming decades can be initially discussed for formulating an activity in the action plan.

In this survey also information on alternatives available or currently already applied or planned to be applied in the uses sectors of HBCD in textiles in transport (alternative materials and alternative flame retardants) would be gathered and noted to support the switch to appropriate alternatives in the phase out of HBCD in the textile sector in the country. Information on alternative on POPs in current use has been compiled by a POPs phase out publication (http://poppub.bcrc.cn/) and further information coming from countries could be included in the update of this publication.

From the information gathered in Tier II the total amount of HBCD in textiles in the transport sector would be estimated. The inventory team would decide depending on the situation in the country and the available capacity what transport sectors would be addressed (cars, busses, trains, ships, air plain). Here the total amount of textiles treated with HBCD or possibly treated with HBCD should be compiled and then multiplied by the range of HBCD concentrations reported for textiles of 2.2 % to 15 % (UNEP 2010a; Kajiwara et al. 2009). This would include an estimate of current use/stocks of HBCD in these sectors, the amount of HBCD imported in the respective inventory year and the amount of HBCD and HBCD containing materials which have entered the end-of-life in the transport sector for the inventory year (and if data are available also the historic amount of HBCD containing waste in this application). Since the use of HBCD is prohibited in textiles an HBCD use might be assumed until approximately 2014 and vehicles produced from 2015 onwards might not contain HBCD. This might be assessed within a tier III inventory.

It is most likely that still information gaps will exist. If these gaps are large then a useful compilation of table 6-3a might not be possible. In this case the information gathered in tier II would be compiled in the inventory report without filling table 6-3a. These gaps might be addressed within a Tier III inventory or formulated as activities in the NIP (see below).

Table 6-3a: Calculation of the amount of HBCD in textiles and associated materials, in use/stocks and in end-of-life in the transport sector

Total amount of textiles treated with HBCD or possibly treated with HBCD, in the transport sector*	**HBCD content in textiles (%)**	**Total amount of HBCD in textiles in transport sector*, in the inventory year**
Amount of textiles in transport sector in current use/stocks likely containing HBCD.	2.2 % to 15 %	Amount of textiles in transport sector in current use/stocks in the market x 2.2% to 15% = …………….kg of HBCD*
Amount of HBCD treated textiles in transport sector imported to the country in the inventory year.**	2.2 % to 15 %	Amount of textiles in transport sector in current use/stocks in the market x 2.2% to 15% = …………….kg of HBCD
Amount of textiles in transport sector* entering the waste stream:	**HBCD content in textiles (%)**	**Total amount of HBCD in textiles in transport sector* entering end o life**
Amount of HBCD treated textiles going to landfill ………………tonnes Amount of HBCD treated textiles incinerated	2.2 to 15 %	Amount of HBCD in textile going to landfill = ……………..kg of HBCD Amount of HBCD in textile going into thermal/ treatment

………………tonnes Amount of HBCD treated textiles going into recycling[11] ………………tonnes		= ………………kg of HBCD Amount of HBCD in textile going into recycling[5] = ……………..kg of HBCD

* Depending on the type of transport (cars, buses, trains, ships, plains) the table can be refined and individual transport sectors listed individually

6.3.2.2. Gathering information and estimating the HBCD amount and related volumes of HBCD containing materials in textile applications used indoor

As mentioned above, a range of textile application in residential homes, public buildings (including hospitals and prisons), air ports or hotels are flame retarded. This might include curtains, textile upholstery of furniture, wall coverings and draperies (UNEP 2010a; Horrocks 2013).

Since POP-PBDEs have also been used in this application as minor uses they also might be included in the assessment if they have not been addressed before (see chapter 6 of POP-PBDE inventory guidance; Secretariat of the Stockholm Convention 2015). In the screening of furniture (couches) PBDEs have been detected in PUR foam (Stapleton et al. 2012).

To gather robust information, industries producing, importing or using textiles in these sectors (textile upholstery of furniture, curtains, bed mattress ticking, wall coverings and draperies), retailers and institutions using these materials (hotels, institutions like hospitals) would be contacted by direct interviews or by questionnaire survey. This contact could be combined with informing these industries and other stakeholders that HBCD is listed in the Stockholm Convention and will not be allowed to be used in new products in these uses.

In the discussion or questionnaire survey with the individual stakeholders, the current and former use of HBCD for the different uses would be clarified as well as the total volume of HBCD currently and historically used in the respective sector. Here also the total volume of textiles which are treated or possibly treated would be noted.

In the discussion or questionnaire approach with the respective industries and/or authorities, flammability standards in the individual uses would be gathered. The requirements of the respective standards would be assessed in respect to the possible (former) use of HBCD in related textile applications.

Assessment and inventory of end of HBCD containing textiles in end-of-life

Other information which would be gathered is the related end-of-life treatment of textiles treated or possibly treated with HBCD. Here information on the former and current end-of-life treatment (including recycling, reuse, treatment, destruction and disposal of HBCD containing textiles) would be gathered including the volumes of possibly HBCD treated materials. [12] Also it would be clarified if these textiles can be removed from other materials or if e.g. for furniture the materials are difficult to be separated or are normally not separated. This would increase the volume of materials which would finally need to be managed in an environmentally sound manner.

[11] The recycling of HBCD containing materials is prohibited by the convention
[12] The related Basel Convention draft technical guidance can be given to the stakeholders.

Here also detailed information on the end-of-life treatment of fractions containing or possibly containing HBCD would be gathered. This would include the information on the amount of materials currently recycled, landfilled or treated in incinerators or cement kilns or by other means. In Tier II a rough estimate of the share of individual end-of-life treatments could be done, similarly as e.g. done in Nigeria for the assessment for their POP-PBDE containing polymers in the transport sector (Babayemi et al. 2012).

In the discussions with the respective HBCD using and applying textile industries also the plans of these industries on managing the HBCD containing stockpiles in textiles can be initially discussed for formulating an activity in the action plan.

In this survey also information on alternatives available or currently already applied or planned to be applied in the uses sectors of HBCD in textiles (alternative materials and alternative flame retardants) would be gathered and noted to support the switch to appropriate alternatives in the phase out of HBCD in the textile sector in the country. Information on alternative on POPs in current use has been compiled by a POPs phase out publication (http://poppub.bcrc.cn/) and further information coming from countries could be included in the update of this publication.

After compilation of the information in Tier II on current and former uses in these applications the total amount of HCBD in these applications would be calculated considering a 2.2 % to 15 % HBCD content in textiles (Kajiwara et al. 2009; UNEP 2010a) or the (average) content which have been applied from the industries for these applications according to the current survey. If only the information that flame retardants have been used in respective applications are used then this should be noted and the estimate then marked as maximum volume of HBCD and HBCD containing materials. This would include an estimate of current use/stocks of HBCD in these sectors, the amount of HBCD newly introduced in the marked for the respective inventory year and the amount of HBCD and HBCD containing materials which have entered the end-of-life in the transport sector for the inventory year (and if data are available also the historic amount of HBCD containing waste in this application).

It is most likely that still information gaps will exist. If these gaps are large then a useful compilation of table 6-3b might not be possible. In this case the information gathered in tier II would be compiled in the inventory report without filling table 6-3b. These gaps might be addressed within a Tier III inventory or formulated as activities in the NIP (see below).

Table 6-3b: Calculation of the amount of HBCD in textiles applications used indoor, in use/stocks and in end-of-life

Total amount of textiles used indoor* treated (or likely treated) with HBCD	**HBCD content in textiles (%)**	**Total amount of HBCD in textiles used indoor***
Amount of textiles used indoor in current use/stocks likely containing HBCD. ………………tonnes	2.2 % to 15 %	Amount of textiles indoor in current use/stocks x 2.2% to 15% = ……………kg of HBCD*
Amount of textiles used	**HBCD content in**	**Total amount of HBCD in textiles used**

indoor* entering end-of-life	textiles (%)	indoor* entering end-of-life
Amount of HBCD treated textiles going to landfill ………………tonnes Amount of HBCD treated textiles incinerated ………………tonnes Amount of HBCD treated textiles going into recycling[13] ………………tonnes	2.2 to 15 %	Amount of HBCD in textile going to landfill = ……………..kg of HBCD Amount of HBCD in textile going into thermal/ treatment = ………………kg of HBCD Amount of HBCD in textile going into recycling[5] = ……………..kg of HBCD

* The individual HBCD containing textiles (e.g. curtains, mattress ticking) present in the country can be listed individually.

6.3.2.3. Gathering information and estimating the HBCD amount and related volumes of HBCD containing materials in textile clothing

As mentioned above, HBCD is also use in textile clothing in particular specific personal protective equipment (PPE) clothing (e.g. for fire fighter and military uniform; other technical textiles). But also in some countries with specific flammability standards for nightwear clothing might require the use of specific materials or labelling or the use of flame retardants.

To gather robust information, industries producing or importing such personal protective textiles, retailers and institutions using these textiles (fire fighters or military) would be contacted by direct interviews or by questionnaire survey. This contact could be combined with informing these industries and other stakeholders that HBCD is listed in the Stockholm Convention and will not be allowed to be used in new products in textiles.

In the discussion or questionnaire survey with the individual stakeholders, the current and former use of HBCD for these uses would be investigated as well as the total volume of HBCD currently and historically used in the respective application. Here also the total volume of textiles which are treated or are possibly treated would be noted.

In the discussion or questionnaire approach with the respective industries and/or authorities, flammability standards in the individual uses would be gathered. The requirements of the respective standards would be assessed in respect to the possible (former) use of HBCD in related textile applications.

Assessment and inventory of end-of-life management from HBCD containing textiles

Other information which would be gathered is the related end-of-life treatment of textiles treated or possibly treated with HBCD. Here information on the former and current end-of-life treatment (including recycling, reuse, treatment, destruction and disposal of HBCD containing textiles) would be gathered including the volumes of possibly HBCD treated materials. [14] Also it would be clarified if these textiles can be removed from

[13] The recycling of HBCD containing materials is prohibited by the convention
[14] The related Basel Convention draft technical guidance can be given to the stakeholders.

other materials or if e.g. for furniture the materials are difficult to be separated or are normally not separated. This would increase the volume of materials which would finally need to be managed in an environmentally sound manner.

Here also detailed information on the end-of-life treatment of fractions containing or possibly containing HBCD would be gathered. This would include the information on the amount of materials currently recycled, landfilled or treated in incinerators or cement kilns or by other means. In Tier II a rough estimate of the share of individual end-of-life treatments could be done, similarly as e.g. done in Nigeria for the assessment for their POP-PBDE containing polymers in the transport sector (Babayemi et al. 2012).

In the discussions with the respective (formerly) HBCD using and applying textile industries also the initial plan of these industries on managing the HBCD containing stockpiles in textiles can be initially discussed for formulating an activity in the action plan.

In this survey also information on alternatives available or currently already applied or planned to be applied in the uses sectors of HBCD in textiles (alternative materials and alternative flame retardants) would be gathered and noted to support the switch to appropriate alternatives in the phase out of HBCD in the textile sector in the country. Information on alternative on POPs in current use has been compiled by a POPs phase out publication (http://poppub.bcrc.cn/) and further information coming from countries could be included in the update of this publication.

After compilation of the information in Tier II on current and former uses in these applications the total amount of HCBD in these applications would be calculated considering a 2.2 % to 15 % HBCD content in textiles (Kajiwara et al. 2009; UNEP 2010a) or the (average) content which have been applied from the industries for these applications according to the current survey. If only the information that flame retardants have been used in respective applications are used then this should be noted and the estimate then marked as maximum volume of HBCD and HBCD containing materials. This would include an estimate of current use/stocks of HBCD in these sectors, the amount of HBCD newly introduced in the marked for the respective inventory year and the amount of HBCD and HBCD containing materials which have entered the end-of-life in the transport sector for the inventory year (and if data are available also the historic amount of HBCD containing waste in this application).

It is most likely that still information gaps will exist. If these gaps are large then a useful compilation of table 6-3c might not be possible. In this case the information gathered in tier II would be compiled in the inventory report without filling table 6-3c. These gaps might be addressed within a Tier III inventory or formulated as activities in the NIP (see below).

Table 6-3c: Calculation of the amount of HBCD in textiles clothing, in use/stocks and end-of-life

Total amount of HBCD treated clothing*	**HBCD content in textiles (%)**	**Total amount of HBCD in clothing in use***
Amount of HBCD treated clothing* in current use/stocks. ………………tonnes	2.2 % to 15 %	Amount of HBCD treated clothing* in current use/stocks x 2.2% to 15% = ……………kg of HBCD*
Amount of HBCD treated	**HBCD content in**	**Total amount of HBCD treated clothing***

clothing* entering end-of-life	textiles (%)	entering end-of-life
Amount of HBCD treated textiles going to landfill ……………...tonnes Amount of HBCD treated textiles incinerated ……………...tonnes Amount of HBCD treated textiles going into recycling[15] ……………...tonnes	2.2 to 15 %	Amount of HBCD in textile going to landfill = ……………..kg of HBCD Amount of HBCD in textile going into thermal/ treatment = ……………..kg of HBCD Amount of HBCD in textile going into recycling[5] = ……………..kg of HBCD

* The individual HBCD containing clothing (e.g. fire fighter uniform, military uniform, others) present in the country might be listed individually.

6.3.3. Tier III: In-depth inventory of HBCD in textile sector

The in-depth inventory can consist of a field survey with detailed assessment of the share of HBCD containing materials in the major applications of HCBD in textiles. This might include the physical screening of textiles for bromine and HBCD.

As mentioned above the amount of HBCD used in the different textile applications is not well documented and most likely have regional differences due to different use volumes in the regions (UNEP 2010a) and national differences due to e.g. differences in national flammability standards. Furthermore the share of HBCD containing products might also depend on flammability standards in the producing/exporting countries. Therefore an inventory of this sector might only lead to reliable and detailed data by involving some monitoring efforts. Such a monitoring could be performed by screenings the bromine content of articles with a handheld XRF equipment (see e.g. *POP-PBDEs BAT/BEP Guidance*[16] (Secretariat of the Stockholm Convention 2014) and *Draft Guidance on Screening and Analysis of POPs in Articles and Product* (Secretariat of the Stockholm Convention 2013). Handheld XRF equipment has been purchased from a range of developing countries in the frame of the NIP update and therefore also these countries would be able to do a national (or even regional) assessment using the XRF screening approach.

According to a first survey, bromine positive tested samples of curtains likely contain HBCD (in Japan 9 out of 10 bromine positive tested curtains contained HBCD as flame retardant) (Kajiwara et al. 2008, 2009). For other applications such as textiles in upholstery in transport considerable amount of PBDEs have been used (Kajiwara et al. 2014). However there might be regional differences in the use of brominated flame retardants. If countries only have XRF as screening tool then the share of bromine positive tested applications might be considered to contain HBCD as a conservative estimate and it should be noted in the inventory report and in NIP report that this might also include textiles containing PBDEs or other brominated flame retardants.

If instrumental analysis is available for the measurement of HBCD in the country then the XRF positive tested

[15] The recycling of HBCD containing materials is prohibited by the convention
[16] This draft guidance document is under revision in accordance with decision SC-6/10.

samples could be further analysed for HBCD for confirmation (GC/MS, GC/ECD or HPLC/MS[17]).

The results of XRF screening (and possibly the confirmation analysis) would be described in the inventory report and would be used for determining national (or regional) impact factors for calculating the share of HBCD containing materials in the individual screened applications. If only XRF analysis has been conducted it would be noted that also other brominated flame retardants (e.g. PBDEs) might have contributed to the bromine positive fraction (see e.g. Kajiwara et al. 2014). Therefore this would be noted in the inventory and suggested for a possibility for refinement in further inventory update.

After Tier III assessments have been done, the tables 6-3a, 6-3b and 6-3c can be filled or refined (instead of using only the information from Tier II assessment).

Another possible Tier III approach could be the development of a material and substance flow analysis of HBCD containing textiles (see e.g. Morf et al. 2007, 2008; Managaki et al. 2009). Material and substance flow analysis can support waste management and material recovery. Dynamic material and substance flow analysis can be used to predict the generation of waste volumes of HBCD containing textiles (see e.g. Morf et al. 2007, 2008). The inventory development of POP-PBDE in WEEE/EEE plastic in Nigeria from Basel Conventional Regional Center has shown that also developing countries are able to use the material and substance flow analysis approach in the frame of Stockholm Convention inventory development (Babayemi et al. 2012, 2014) using the free software for material/substance flow analysis from Vienna University (http://www.stan2web.net/). Such or similar approaches could be used in the development of an in-depth Tier III inventory.

6.4. Step 4: Managing and evaluating data

In the data evaluation step the data 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 inadequate, further data collection or screening (Tier III) can be undertaken. Otherwise the gaps would be noted in the inventory.

When a country improves the inventory of the HBCD use over time, the data quality will become better and more reliable. Since different countries/Parties will develop HBCD inventories results in other countries from the region might be assessed and information exchanged and inventories improved by additional information.

Also the regional Stockholm and Basel Convention Centres might be contacted to evaluate if regional information on HBCD use in textile applications is available in the region.

6.5. Step 5: Preparing the inventory report

The final information and data for HBCD use and presence in the different textile applications in the country would be accompanied by the methodology used and the detailed calculations and assumptions done in the calculations as an audit trail in a separate chapter of the HBCD inventory report. All country-specific adjustments and estimates would be noted and described.

To provide an overview on the presence of HBCD at the national level, as well as on the amount of the HBCD impacted volumes of textile materials to be managed during the NIP implementation phase, the information which could be included in dedicated NIP paragraphs may comprise of a brief summary on:

[17] Only the HPLC/MS is capable to analyse the individual diastereomers (which is not required for the inventory).

- Key information gathered on the use of HBCD in the different textile applications (transport sectors, different indoor uses and clothing).
- Estimated likely total amount of HBCD in the individual textile sector and volume of possibly HBCD containing textiles;
- Monitoring efforts done during inventory development;
- Gaps in these data;
- Amount of (potentially) HBCD containing textiles currently entering the market (please note that this is not allowed if HBCD use has entered into force for the country);
- Regulations on flammability standards in the country requiring and determining flame retardant use for certain textile applications;
- Alternatives available and used for the different textile applications;
- End of end-of-life management of HBCD containing textiles including reuse, recycling[18], treatment, destruction and disposal of HBCD containing textiles. For compiling the information also consult the related Basel Convention guideline draft (Secretariat of the Basel Convention 2014).

While some of these information can be generated from a Tier I and Tier II inventory some of the listed information might only be included if a Tier III inventory approach has been used.

Also further activities suggested for assessing and managing the use of HBCD in the different textile applications would be included in the NIP.

[18] Please note that the recycling of HBCD containing materials is not exempted in the Stockholm Convention.

7. Inventory of HBCD in minor uses

The**re** are a range of other uses of HBCD which, however, are considered rather minor uses. These uses – HIPS in EEE and paints, latex binder and glues - are shortly introduced in this chapter with some considerations on possible inventory activities.

7.1. HBCD use in electrical and electronic equipment (EEE) and related wastes

HBCD has also been used as BFR in high impact polystyrene (HIPS) in casings of electrical and electronic equipment (EEE) (UNEP 2010a). Therefore HIPS plastic casings or parts of electronics as well as WEEE plastic fractions from recycling might contain HBCD. In a Swiss survey of individual EEE equipment (IT equipment and TVs) approximately 18% of IT equipment and 3% of TV housings made from HIPS contained HBCD (Wolf 2001; Waeger et al. 2010).

In a first comprehensive screening of BFRs in mixed WEEE plastic from shredders of the major WEEE categories in several European countries, however, did not detect HBCD with a detection limit for HBCD of 0.2 g/kg plastic (200 ppm) (Waeger et al. 2010; Waeger et al. 2012). Therefore it seems that the average HBCD concentration in European WEEE plastic is below this concentration. Since a large share of European WEEE plastic stem from Asia this might also indicate that the average HBCD concentration in WEEE plastic from Asia might in average be below the 200 ppm (which was a relative high detection limit).

Also in a survey on the occurrence of brominated flame retardants in black thermo cups and selected kitchen utensils purchased on the European market no HBCD was detected while technical decabromodiphenyl ether (decaBDE) and other BFRs such as tetrabromobisphenol A (TBBPA), tetrabromobisphenol A bis(2,3-dibromopropyl), ether (TBBPA-BDBPE) and decabromodiphenylethane (DBDPE) were identified (Samsonek & Puype 2013). Also this study indicates that the overall level of HBCD in flame retarded waste plastic recycled into (such) products seems low.

Therefore currently no emission factors can be given for HBCD in mixed WEEE plastic but this is probably below 200 ppm. Therefore the overall relevance of HBCD in WEEE plastic is considered low and no specific inventory activity is recommended. Since for POP-PBDE the major inventory activity is normally for WEEE polymers (see POP-PBDE inventory guidance (Secretariat of the Stockholm Convention 2015)), this material flow and related management of POP-BFRs in WEEE plastic are normally addressed within the action plan of POP-PBDEs.

If a country decides to develop a HBCD inventory in WEEE plastic then it is recommended to do measurements of HBCD (and other POPs-BFRs) in WEEE plastic to develop impact factor for the country or region considering e.g. the approach of Waeger et al. (2010) however with lower detection limit for HBCD in WEEE plastic (e.g. 10 or 20 ppm).

Also if a country has a WEEE recycling sector with separation of different plastic fractions and types then the HIPS fraction could be assessed for HBCD content.

Then based on these measurements a HBCD inventory in WEEE plastic and in the HIPS plastic fraction can be developed.

7.2. HBCD use in paints, coatings, glues and latex binders

The use of HBCD in paints/coatings, latex binders and glues has been reported (Albemarle Corporation 2000, Great Lakes Chemical Corporation 2005). However these were minor uses and have not been confirmed for different regions (European Commission 2008). Therefore it is recommended to address these uses only if a detailed Tier III inventory is developed.

For these uses producers of HBCD might directly contacted to find out more details on these uses and on possible regional uses. Alternatively also producers of paint and latex binder could be contacted and asked for HBCD or general flame retardants in these applications.

If assessment and inventory activities of HBCD use in paints/coatings and latex binders are developed then it might be useful to assess the POPs use in these applications in a more comprehensive manner. The most prominent POP formerly used in paints and coatings were PCBs which still have relevance for human and food exposure due to the durability of these paints and coatings (Jartun et al. 2009; Wagner et al. 2014, Zennegg et al. 2014). In these applications PCBs in paints and coatings have been substituted by short chain chlorinated paraffins which are currently assessed by the POPs Review Committee (UNEP 2012). Furthermore pentachlorophenol (PCP) has been used in wood paints and impregnation (UNEP 2014)[19] which has been assessed by the POPRC and is considered by the COP in May 2015.

Therefore if a HBCD inventory team decides to assess HBCD in paints/coatings and latex binders then it could be discussed if the relevance of other POPs in these uses might be included in such an assessment.

[19] Also lead in paints is addressed by the Global Alliance to Eliminate Lead Paint including UNEP.

8. Inventory of contaminated sites containing HBCD

8.1. Scope and background information

In accordance with the provisions of Article 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 HBCD-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 give guidance for the identification of HBCD-contaminated sites for the inventory. In doing so, the inventory team is recommended to also consider the step-by-step approach in UNIDO's *Persistent Organic Pollutants: Contaminated Site Investigation and Management Toolkit* (UNIDO, 2010), which contain the identification of POP-contaminated sites (not specifically covering HBCD sites yet), assessing related risks and setting priorities.

The inventory would compile to report information collected during the site investigation from Module 2, preliminary site investigation, stage 1 and/or stage 2, of the Toolkit. This information includes the site profile, past and present activities, spill releases, and site owners.
As for other POPs, contaminated sites might be generated in the entire lifecycle of the respective POP including production of HBCD, production of products containing HBCD, use of these products, recycling and the end-of-life of these products. Also for HCBD landfills are one ultimate destination of HBCD-containing materials in particular in countries without destruction capacity. Brominated flame retardants including POP-PBDEs and HBCD can to some extent be released from these materials by landfill leachate or from landfill fires (Danon-Schaffer et al. 2014; Gullett et al. 2009; Odusanya et al. 2009; Weber et al. 2011, Remberger et al. 2004).

To carry out the contaminated site inventory, the team is expected to also utilize information provided and gathered in chapters 3 to 7 and the outcome of the related inventories for tracking potential hot spots, while also examining the solid waste management/practice of the individual HCBD producers, users and uses in the country.

A step-by-step guidance for the inventory of HBCD contaminated sites also considering a Tiered approach is given below.

Please note: A site is generally considered contaminated by POPs when the concentration of one or more contaminants exceeds the regulatory criteria or poses a risk to humans and/or the environment. Since currently no regulation limits for HBCD in soil exist, contamination can only be compared to background levels. Background levels in soils e.g. in the UK in rural area were 0.07 ng/g while in London city up to 420 ng/g were detected (Harrad et al. 2010a).

8.2. Step 1: Planning the inventory

Information from the identified relevant sectors (chapter 3 to 7) could be used to identify potential HBCD-contaminated sites and then set priorities for remediation. A list of potentially contaminated sites

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

An inventory of HBCD contaminated sites would include an assessment of releases and related contamination along the life cycle (see Table 8-1):

- Production sites;
- HBCD containing EPS and XPS in stocks/use in buildings and construction;
- HBCD containing EPS and XPS in use and stocks in packaging, furniture and other;
- HBCD in EPS and XPS in recycling and end-of-life.

Appropriate members of the inventory task team need to be selected to conduct the inventory of this sector. Specific stakeholders for the inventory of HBCD are listed in Table 3-1. The core inventory team could be extended as appropriate. The NIP coordinator or task team leader can decide which stakeholder would be included in an inventory team and which stakeholder would just be contacted for an interview or with a questionnaire.

Identification of stakeholders

Identification of stakeholders could consider all those listed in Table 3-1, 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.

- Authorities and other stakeholders that might provide valuable information on identified contaminated sites, that might contain HBCD:
    - Environmental protection agencies;
    - Municipal authorities;
    - State governments;
    - Ministries of environment;
    - Ministries of industry;
    - Stakeholders of fire fighting foam use and identified industrial use;
    - Oil producing and service companies;
    - Urban and city planning authorities;
    - Industry (to be contacted to gather information);
    - Producers of HBCD;
    - Users;
    - Property development companies.

Environmental contamination from releases from processes and deposits can affect air, water/sediments and land as well as biota including food. Therefore, the investigation is necessary to identify the relevant sectors involved, manufacturing and wastes being disposed, biosolids application, methods of waste disposal or treatment, and recycling and related waste disposal locations and related releases. Potential HBCD-contaminated sites are listed in Table 8-1 below. 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.

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

8.3.1. Tier I: Initial assessment of potentially HCBD contaminated sites

The expected output of the initial assessment includes:

- List of relevant stakeholders in the country;
- Compilation of information on HBCD contaminated sites;
- List of locations of potentially HBCD contaminated sites;
- Compilation of gaps from Tier 1 assessment to be addressed by Tier II.

Gathering information on HBCD contaminated sites

In the first step an overview information on HBCD contaminated sites (internet and literature survey). There are already a range of studies published on environmental contamination from HBCD production and use and related releases. There are already a wide range of publications and reports on HBCD contaminated sites which might be consulted as a first step:

- o Contamination at/around HBCD production sites (Allchin & Morris 2003 ; Morris et al. 2004; Li et al. 2012, Rüdel et al. 2012);
- o Contamination from HBCD using industries (plastic, textile, etc) and micronizing of HBCD (Eljarrat et al. 2005; Eljarrat et al. 2011; Morris et al. 2004; Remberger et al. 2004; Rüdel et al. 2012; Sellstroem et al. 1998; Zhang et al. 2013);
- o Recycling of HBCD containing wastes (Gao et al. 2011; Tomko & McDonald 2013);
- o Landfills and dump sites (Remberger et al. 2004; Weber et al. 2011);
- o Application of highly contaminated industrial sludge from (industrial) waste water treatment.

Table 1: Potential HBCD-contaminated sites or hot spots

Live cycle stage; Sector	Activities	Locations
HBCD production	(Former) Production	Production site
	(Former) Destruction of production waste	Sites where production waste has been destroyed
	Disposal of waste from production	Landfills related to waste from production
	Former water discharge	River sediment and banks related to releases from production site
Sites where EPS and XPS have been used in production	EPS/XPS industry (formerly) using HBCD	Site of production; Landfill site of related wastes; Impacted surface waters (sediment and flood plains)
	Textile industry and other industries (formerly) using HBCD	Site of production; Landfill site of related wastes;

		Impacted surface waters (sediment and flood plains)
	Factories micronising HBCD	Site of production; Landfill site of related wastes; Impacted surface waters (sediment and flood plains)
Use of HBCD	Sites where EPS and XPS is used	Soil impacted from buildings/city[20]
	Accidental fire in building	Soil/environment around fire accidents with HBCD XPS/EPS
End-of-life treatment	Recycling area of HBCD containing materials	Recycling areas and landfills with deposited wastes
	Deposition of HBCD-containing waste	Landfill and surrounding from leachate from HBCD- containing wastes
	Open burning or non-BAT incineration of HBCD-containing waste[21]	Related sites and sites were residues/ashes are disposed
	Application sites of HBCD impacted sewage sludge	Agriculture land

8.3.2. Tier II: (Preliminary) Inventory of potentially HCBD contaminated sites

The expected output of the initial assessment of HBCD contaminated sites includes:

- Gathering information on individual site type in the country;
- Detailed locations of potentially contaminated sites (GIS);
- Information by site visits of selected potentially contaminated sites;
- Information on the potentially HBCD contaminated sites allowing priorisation;
- Information on possible human exposure (e.g. if HBCD measurement of fish exist (see e.g. Rüdel et al. 2012) or levels in chicken eggs around the site);
- Compilation of gaps from Tier II assessment to be possibly addressed by Tier III.

Gathering information on potentially HBCD contaminated sites

Information would be collected by direct contacts, by questionnaire approach or by site visits from (selected) sites listed in Table 8-1.

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;

[20] The comparison of HBCD in soils in UK cities compared to rural environment revealed higher levels in cities with some peak concentration in city soil (Harrad et al. 2010).

[21] The combustion of HBCD-containing waste in state of art incinerators does not lead to relevant releases of HBCD or PBDD/F (Mark et al. 2015; Weber et al. 2003).

- Potential of food and feed contamination.

Carrying out the PSI stages 1 and 2 for those locations of potential HBCD contamination listed in Table 8-1 is suggested for the purposes of the inventory.
The objective of PSI stage 1 is to gather sufficient information to estimate the likelihood of POPs contamination that may be present at a site. Sampling relevant environmental media and investigations of subsurface conditions are not required at this stage.

A 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. This would include information such as:
    - How long have HBCD been produced or used at the site?
    - What other polluting processes or chemicals were and are present?
    - Information on accidents and spills;
    - Practices and management relating to potential contamination at the site and at adjacent sites (including related landfills or thermal treatment of wastes);
    - Waste water treatment;
    - Possible releases to surface water.
- **Site visits:** one or more walk-through site visits to verify and complete the information gathered during the literature review for indicators or presence of contamination; in these site visits the also possible exposure to livestock, fish and humans in the vicinity would be noted.
- **Interviews:** interviews to verify and complete information by asking 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 might be accessible in industrial countries, it is not always available or accessible in developing countries.
One outcome of Tier II assessment would also be a gap assessment of further information needed for selected sites and a prioritization of possible Tier III assessment of selected sites (in particular considering the source strength of sites and the risks to humans.

8.3.3. Tier III: In depth inventory of potentially HBCD contaminated sites

Tier III would include PSI stage 2 assessments and possibly measurements of HBCD contamination if such studies can be conducted.

PSI stage 2 would be conducted only if stage 1 indicates that there is a likelihood of HBCD/POP contamination at the site or if there is insufficient information to conclude that there is no potential for HBCD/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 would 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.

Key elements of a conceptual site model include:

- 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;
- Receptors and risk.

8.4. Step 4: Managing/evaluating data

The information on the different potentially HBCD contaminated sites would be compiled and evaluated. The compilation would best be done according to the life cycle of HBCD (Table 2-1).

The contaminated sites data would best be included in a national contaminated site database. If such a database does not exist then the different POPs contaminated sites (PCBs)

Based on the data collected, a conceptual site model (CSM) can be developed to establish the relationship between the contaminants, exposure pathways and receptors (see figure 8-1). 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.

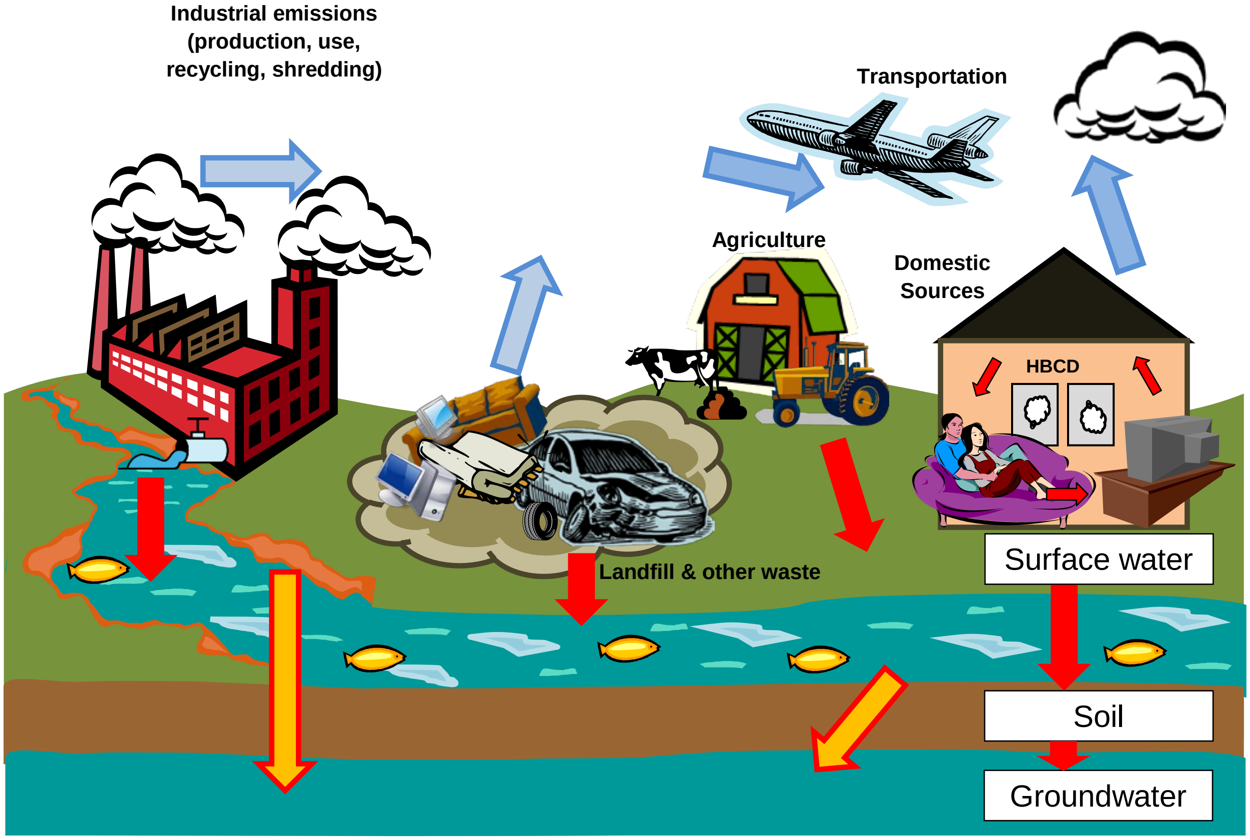


Figure 0-1: Routes of contamination migration

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, data management, and evaluation could refer to the *Contaminated Site Toolkit* (UNIDO 2010).

8.5. Step 5: Reporting of potential HBCD-contaminated sites

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 national contaminated sites database and in the NIP report. Also further activities needed for assessing and possibly securing or cleaning of contaminated sites would be include 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 have been** 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 HBCD-containing materials disposed;
- The names and addresses of those entities responsible for disposal of HBCD-containing materials;
- 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 ongoing 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 HBCD at the national or international level. Therefore for the time being, levels at HBCD contaminated sites might be compared to background levels and other contaminated sites reported in literature (Li et al. 2012). 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.

9. Alternatives for HBCD

9.1 Potential alternatives

To reduce the risks to human health and the environment the use of HBCD for different applications must be minimized. The target or aim of any risk reduction strategy for HBCD should be to reduce and eliminate emissions and releases taking into consideration the indicative list in Annex F of the Stockholm Convention including technical feasibility of possible control measures and alternatives, the risk and benefits of the substances and their continued production and use. In considering any strategy for a reduction in such risks, it is important to consider the availability of substitutes in the sectors of concern. In this regard, the replacement of HBCD by another chemical or non-chemical alternative needs to take account of factors such as (UNEP 2011):

- technical feasibility (practicability of applying an alternative technology that currently exists or is expected to be developed in the foreseeable future);
- costs, including environmental and health costs;
- risk (safety of the alternatives);
- availability and accessibility of substitutes in the sectors of concern.

Information on available alternatives for HBCD is presented in the Draft risk management evaluation on hexabromocyclododecane (UNEP/POPS/POPRC.7/5), developed by POP Reviewing Committee (UNEP 2011). Also, information on HBCD alternatives have been collected in a living document, namely the *Publication on POPs in Articles and Phasing-Out Opportunities (*http://poppub.bcrc.cn/*)*, developed by the Stockholm Convention Regional Centre for Capacity-building and the Transfer of Technology in Asia and the Pacific and Basel, Rotterdam and Stockholm Secretariat in 2014. The publication aims at assisting Parties and others in their implementation by providing a compilation of information on alternatives to POPs in current uses.

There is a range of approaches available to substitute the use of HBCD in all applications.

These approaches can be grouped into the following three categories: Flame Retardant Substitution, Resin/Material Substitution and Product Redesign (UNEP 2011). This chapter gives a first introduction on the first two approaches when identifying potential alternatives for HBCD and some considerations on health when selecting a substitution. More details can be found in Part III of the *Publication on POPs in Articles and Phasing-Out Opportunities (*http://poppub.bcrc.cn/*).*

Further information on criteria for selecting alternatives is compiled in the *Publication on POPs in Articles and Phasing-Out Opportunities (*http://poppub.bcrc.cn/),and in the OECD Substitution and Alternatives Assessment Toolbox (http://www.oecdsaatoolbox.org/).

9.1.1. Flame Retardant Substitution

The primary use for HBCD is for expanded polystyrene (EPS) and extruded polystyrene (XPS) foam insulation (more than 97%). Typical loading for EPS is between 0.5% and 0.7%. The average HBCD loading in XPS is about 2% Its minor uses include textile back coatings (approximately 2-3% of total HBCD use) and high impact polystyrene (HIPS) used in electronics housings (approximately 4% of total HBCD use). The following content is classified by these three applications (ChemSec 2011, EUMEPS 2002, UNEP 2011, US EPA 2011).

9.1.1.1 EPS and XPS alternatives

(a) Emerald 3000

According to the manufacturer, Emerald 3000 has been designed to provide flame retardant properties at low loadings to polystyrene foam to meet industry fire norms such as ignition resistance (Davis 2011). Emerald 3000 is expected to provide comparable fire performance to HBCD in flame retarded EPS and XPS. It is also expected to require minimal reformulation to use in existing production lines (Chemtura 2012). Some manufacturers of polystyrene foams, including BASF, anticipate that use of Emerald 3000 would result in a functionally equivalent product (Smock 2011). Extensive test series with Emerald 3000 on a small-to-medium scale have yielded promising results. BASF plans to test new product formulations on a larger scale as soon as sufficient amounts of the polymer become available.

(b)Tetrabromobisphenol-A bis (allyl ether)

A study on flame retardants listed TBBPA bis(allyl ether) seems a possible alternative chemical for HBCD in EPS and XPS applications (Morose 2006). TBBPA bis(allyl ether) is marketed by Chemtura as a flame retardant for EPS insulation foams, providing indication that its performance attributes are similar to HBCD is EPS applications (KLIF 2011).

(c)Dibromoethyldibromocyclohexane

Dibromoethyldibromocyclohexane is among the most common flame retardants used as alternative in EPS and XPS (Swedish Chemical Agency 2005). It is marketed by Albemarle under the trade name SAYTEX BCL 462 (Albemarle 2005). Dibromoethyldibromocyclohexane is therefore technically feasible.

(d)Non-flame retarded EPS and XPS in combination with thermal barriers (e.g. concrete)

Non-flame retarded EPS and XPS insulation foams in combination with other construction materials are used in several countries to protect the EPS and XPS from catching fire. For example in Sweden and Norway, national regulations allow the use of non-flame retarded insulation materials, provided the total building element meets fire safety requirements. In these countries, EPS in combination with thermal barriers (non-combustible materials with high heat thermal capacity such as concrete) are used as alternatives to flame retarded EPS and XPS. Use of EPS in combination with thermal barriers reduces the need for flame retarded EPS without compromising fire safety performance in constructions (KLIF 2011). In the U.S. and Canada, where it appears that there are material requirements for insulation materials, EPS and XPS in building applications would most likely contain flame retardants (Blomqvist 2010). The Norwegian Climate and Pollution Agency concludes that the best way to prevent the spread of fire is by adequately protecting insulation materials from any ignition source. Industry recommendations are that EPS should always be protected with facing materials including concrete, bricks, plasterboards, metal sheet, etc. Insulation materials should be covered during their use so as to provide the required fire performance and for mechanical and long-term insulation properties. By covering EPS and XPS insulation foams with concrete on all sides, the building element as a whole could be classified as non-combustible and used in construction. Non-flame retarded EPS insulation foams can also be covered with a layer on non-combustible insulation material such as mineral wool. This is particularly suitable for flat roofs. In all solutions involving non-flame retarded EPS and XPS, the layer of non-combustible material will have to fully cover the insulation material on all sides and precautions have to be taken to avoid openings and penetrations in the construction such as around windows (KLIF 2011).

9.1.1.2 HIPS alternatives

For HIPS alternatives, there are at least five substance, Resorcinol bis (biphenyl phosphate) ,Bisphenol A bis (biphenyl phosphate), Diphenylcresyl phosphate,Triphenyl phosphateand alloys of PPE/HIPS treated with halogen-free flame retardant alternatives. For resorcinol bis (biphenyl phosphate), specific information is unavailable to describe the performance of resorcinol bis (biphenyl phosphate), bisphenol A bis (biphenyl phosphate) and diphenylcresyl phosphate in HIPS. Nonetheless, in view of the fact that HBCD is not widely used in HIPS and these alternatives were preliminary identified to be technically feasible, it is possible that these substances are being used and that their performance attributes are similar to that of HBCD (Maag et al. 2010). And With respect to PPE/HIPS, major European manufactures of television sets appear to be using alloys including PPE/HIPS with non-halogenated flame retardant. This is an indication that alloys of PPE/HIPS with non-halogenated flame retardant also perform to required industry standards. Alloys of PPE/HIPS are known to have relatively higher inherent resistance to burning and spreading fire because they form an insulating char foam surface when heated. They also have higher impact strength and give similar design opportunities for parts with fine structural details. In addition, alloys of PPE/HIPS require fewer changes to the expensive molds and tooling used in the molding process (Maag et al. 2010).

9.1.1.3 Textile back coating alternatives

Intumescent systems containing a dehydrating component, a charring component and a gas source

Intumescent systems have successfully shown their potential. Several intumescent systems for textile applications have been on the market for about 20 years (Posner et al. 2010). They are based on the formation of expanded coal tar, which partly acts as an insulating barrier against heat and as a smoke-fume trap. Intumescent systems for textile back coating require special handling in application to ensure that the systems work as intended. It is important that the best conditions and combinations of the 3 different components of the systems are in an evenly and well distributed dispersion in the textile application for the desired flame protection to be achieved (Posner 2004).

9.1.2. Resin/Material Substitution

A variety of insulation materials are used in buildings, each having some advantages for specific applications determining its use, and many with general application. In terms of market volumes the major insulation materials apart from the EPS/EXS are mineral wool, fibre glass wool and polyurethane rigid foams, but a number of other insulation materials are used to some extent.

Non-flame retarded EPS boards are used in a number of countries in combination with other construction materials which protect the EPS from catching fire. A widely applied construction is as ground or floor insulation below a concrete layer, but also walls and other more open constructions may be made with regular EPS boards which are not flame retarded if thermal barriers are applied.

（a）Stone wool

Stone wool is made from volcanic rock, typically basalt or dolomite, an increasing proportion of which is recycled material in the form of briquettes. Slag wool is made from blast furnace slag (waste). The stone wool is a subgroup of the mineral wool together with glass wool. Over the last decade, glass wool, rock (stone) wool and slag wool have together met just over half of the world demand for insulation.

After the furnace, droplets of the vitreous melt are spun into fibres. Droplets fall onto rapidly rotating flywheels or the mixture is drawn through tiny holes in rapidly rotating spinners which shapes it into fibres. Small quantities of binding agents are added to the fibres for adhesion. The structure and density of the product can be adapted to its precise final usage. Inorganic rock or slag is the main components (typically 98%) of stone wool. The remaining 2% organic content is generally a thermosetting resin binder (an adhesive), usually phenol formaldehyde and a little mineral oil.

（b）Glass wool (fibre glass insulation)

For glass wool the raw materials are sand, limestone and soda ash, as well as recycled off cuts from the production process. The glass wool is a subgroup of the mineral wool.

The raw materials are melted in a furnace at very high temperatures, typically 1300 to 1500 °C. In insulation fibre glass borates act as a powerful flux in the melt as it lowers glass batch melting temperatures (Floyd et al., 2008). After the furnace, droplets of the vitreous melt fall onto rapidly rotating flywheels or the mixture is drawn through tiny holes in rapidly rotating spinners which shapes it into fibres for adhesion. Small quantities of binding agents are added to the fibres. Glass wool products usually contain 95% to 96% inorganic material (Eurima 2011).

（c） Phenolic foams

Phenolic foam insulation is made by combining phenol-formaldehyde resin with a foaming agent. When hardener is added to the mix and rapidly stirred, the exothermic reaction of the resin, in combination with the action of the foaming agent, causes foaming of the resin. This is followed by rapid setting of the foamed material (Greenspec 2011). In the process phenol is polymerized by substituting formaldehyde on the phenol's aromatic ring via a condensation reaction and a rigid thermoset material is formed. Compared to the EPS/XPS and PUR/PIR, the market share of the phenolic foams seems to be small due to higher prices.

（d）Natural fibre-based insulation materials

Various modern insulation materials are based on natural fibres, primarily plant fibres but also sheep wool. Some of these have been known for centuries but have got a renaissance over the last decades with the growing interest for environment friendly building techniques. They are available as loose insulation fill, as insulation batts or/and as rolls.

（e）Other natural fibre-based insulation materials

As mentioned, a number of the other natural fibre-based insulation materials have been considered as alternatives to flame retarded EPS, but not further assessed due to limitations of the study.

9.1.3. Specialty and Emerging Alternative Materials

The insulation materials presented in this section may be functional alternatives to EPS and XPS, but are not considered to be currently viable for large scale building applications, and so are constrained to specialty applications or limited geographic areas. This information is intended to provide context in case changes in manufacturing processes or economies of scale allow these products to become viable in the future.

(a) **Aerogel** is available as a rigid board, roll, or loose-fill; and is used to insulate underfloors, rainscreens, roofing, cathedral ceilings, and interior walls (Madonik 2011). It is made from silica gel, polyethylene terephthalate (PET), fiberglass, and magnesium hydroxide (COWI 2011). Aerogel is lightweight and has a very high R-value of 10, but is costly.

(b)**Carbon foam** is a type of rigid board foam made from calcined coke. It is manufactured in limited quantities and is used primarily as a specialty insulation in the aeronautic, marine, and energy industries (Madonik 2011).

(c)**Foamglas** is a rigid board insulation made from sand, limestone, and soda ash that is primarily used for high-temperature industrial applications where extreme heat resistance is required but can be used to as insulation in roofs, walls, and below-grade.

(d)**Phenolic foam** is a type of rigid foam and foamed-in-place insulation that may be used in roofing, wall cavities, external walls, and floors (COWI 2011). Currently, only foamed-in place phenolic insulation is available in the U.S (U.S. Department of Energy 2011). Rigid phenolic foams are no longer produced in the U.S. after corrosive breakdown products caused construction issues in the early 1990s, although they may be imported from Europe and Asia (Smith et al. 1993; Schroer et al. 2012).

(e)**Reflective insulation** is a foil-faced insulation material that incorporates a radiant barrier (normally highly reflective aluminum) with a kraft paper, plastic film, polyethylene bubble, or cardboard backing (U.S. Department of Energy 2012). Reflective insulation is used to reduce radiant heat flow across an open space, most usefully for downward radiant heat flow, and is typically used between roof rafters.

(f)**floor joists**, and wall studs (U.S. Department of Energy 2008). The rest of the insulations described here are designed to reduce thermal heat conduction through solid surfaces in any direction. For this reason, reflective insulation is not an alternative for EPS and XPS, but rather works best in complement with other forms of insulation.

(g)**Agrifiber** insulation is manufactured from agricultural waste (e.g., rice hulls, fungal mycelia, wheat or rice straw) and is available as board insulation (Healthy Building Network 2011; Wilson 2011). Agrifiber typically uses borate as a flame retardant (Sustainable Sources 2011). New agrifiber insulations under development using mycelium as a binder are reported to have obtained a Class 1 fire rating without use of added chemical flame retardants (Wilson 2011). Agrifiber insulation has an R-value ranging from 3.0 to 3.5 and is not water resistant; it is currently available only in limited SIPs applications (Healthy Building Network 2011; Madonik 2011).

9.2 Criteria for flame retardant alternatives

When selecting flame retardants, decision-makers will consider performance and cost in combination with the human health and environmental information. The evaluation of the flame retardant alternative should consider the entire life cycle of the product including recycling and end-of-life treatment (UNEP 2010b,c; Shaw et al. 2010).

Criteria for the use of flame retardants have been compiled in table 9-1.

Table 9-1: Criteria for flame retardant alternatives

Considerations	Details
Hazard Considerations	(1) human health hazard (2) ecotoxicity (3) persistence (4) bioaccumulation potential (5) exposure potential
	(1)occupational

Social Considerations	(2)consumer and life stage (3)environmental justice (4)additional social considerations for application to their own decision-making processes
Performance and Cost Considerations	This is intended to allow companies to develop marketable products that meet performance requirements while reducing risk associated with potential hazard and exposure attributes

9.2.1. Hazard Considerations criteria

Table 4-2 summarizes the criteria that were used by DfE to interpret the data presented in the hazard profiles. The same criteria are used to evaluate hazard for all alternatives assessments conducted by DfE since 2011. These criteria, collectively known as DfE Alternatives Assessment Criteria for Hazard Evaluation, underwent Agency-wide and public comment, and were finalized in 2011 (U.S. EPA 2011b). A hazard designation for each human health endpoint was not given for each route of exposure but rather was based on the exposure route with the highest hazard designation. Data may have been available for some or all relevant routes of exposure.

The details as to how each endpoint was evaluated are described below and in the DfE full criteria document, DfE Alternatives Assessment Criteria for Hazard Evaluation, available at: http://www.epa.gov/dfe/alternatives_assessment_criteria_for_hazard_eval.pdf.

Table 9-2: Criteria Used to Assign Hazard Designations

Endpoint	Very High	High	Moderate	Low	Very Low
Human Health Effects					
Acute mammalian toxicity/ Carcinogenicity / Mutagenicity / Genotoxicity / Reproductive toxicity / Developmental toxicity / Neurotoxicity / Repeated-dose toxicity /Sensitization / Irritation, corrosivity / Endocrine activity					
Environmental Toxicity and Fate					
Aquatic toxicity					
Environmental persistence					

Several additional endpoints were characterized, but not evaluated against hazard criteria. This is because the endpoints lacked a clear consensus concerning the evaluation criteria (endocrine activity), data and expert judgment were limited for industrial chemicals (persistence in air, terrestrial ecotoxicology), or the information was valuable for the interpretation of other toxicity and fate endpoints (including toxico-kinetics and transport in the environment).

Table 9-3: Definitions of Endpoints and Information Characterized but Not Evaluated Against Hazard Criteria

Toxicological Endpoint	Definition
Toxicokinetics	The determination and quantification of the time course of absorption, distribution, biotransformation, and excretion of chemicals (sometimes referred to as *pharmacokinetics*).
Biomonitoring Information	The measured concentration of a chemical in biological tissues where the analysis samples were obtained from a natural or non-experimental setting.
Environmental Transport	The potential movement of a chemical, after it is released to the environment, within and between each of the environmental compartments, air, water, soil, and sediment. Presented as a qualitative summary in the alternative assessment based on physical-chemical properties, environmental fate parameters, and simple volatilization models. Also includes distribution in the environment as estimated from a fugacity model[1].
Persistence in Air	The half-life for destructive removal of a chemical substance in the atmosphere. The primary chemical reactions considered for atmospheric persistence include hydrolysis, direct photolysis, and the gas phase reaction with hydroxyl radicals, ozone, or nitrate radicals. Results are used as input into the environmental transport models.
Immunotoxicology	Adverse effects on the normal structure or function of the immune system caused by chemical substances (e.g., gross and microscopic changes to immune system organs, suppression of immunological response, autoimmunity, hypersensitivity, inflammation, and disruption of immunological mechanistic pathways).
Terrestrial Ecotoxicology	Reported experimental values from guideline and non-guideline studies on adverse effects on the terrestrial environment. Studies on soil, plants, birds, mammals, invertebrates were also included.
Endocrine Activity	A change in endocrine homeostasis caused by a chemical or other stressor from human activities (e.g., application of pesticides, the discharge of industrial chemicals to air, land, or water, or the use of synthetic chemicals in consumer products.)

(U.S. EPA 2012c). 1A fugacity model predicts partitioning of chemicals among air, soil, sediment, and water under steady state conditions for a default model "environment".

9.2.2. Social Considerations

Occupational Considerations: Workers might be exposed to relatively high concentrations of flame retardant chemicals from direct contact when conducting specific tasks related to manufacturing, processing, and application of chemicals. For example, tasks that involve heat and pressure where materials are aerosolized as they are mixed and reacted may result in direct contact with flame retardant chemicals. Many facilities have established risk management practices, which are required to be clearly communicated to all employees. The National Institute for Occupational Safety and Health (NIOSH) has established a hierarchy of exposure control practices. Starting with the most protective, the practices are: elimination, substitution, engineering controls, administrative controls, and personal protection. Switching to inherently low hazard chemicals can benefit workers by decreasing workplace risks through the best exposure control practices: elimination and substitution of hazardous chemicals with safer alternatives.

Consumer and Life-stage Considerations: Consumers are potentially exposed to flame retardant chemicals through multiple pathways (Harrad et al. 2008; Imm et al. 2009; Shaw et al. 2010). Exposure research provides evidence that people carry body burdens of flame retardants, including HBCD. Individuals may also experience disproportionate impacts during certain life stages resulting from higher exposures, increased susceptibility in response to exposure, or both conditions (National Academy of Sciences 2008).

Environmental Justice Considerations: At EPA, environmental justice concerns refer to disproportionate impacts on minority, low-income, or indigenous populations. These disproportionate impacts arise because these population groups may experience higher exposures, are more susceptible in response to exposure, or experience both conditions. Factors that are likely to influence resilience/ability to withstand harm from a toxic exposure can vary with socio-demographics (e.g., co-morbidities, diet, metabolic enzyme polymorphisms, etc.) and are therefore important considerations. Adverse outcomes associated with exposure to chemicals may be disproportionately borne by minority and low income populations. Additional information about EPA's environmental justice policy can be accessed at: www.epa.gov/compliance/ej/resources/policy/considering-ej-in-rulemaking-guide-07-2010.pdf.

9.2.3. Performance, Availability, Accessibility and Cost Considerations

The DfE approach allows companies to examine hazard profiles of potential replacement chemicals so they can consider the human health and environmental attributes of a chemical in association with cost and performance considerations. This is intended to allow companies to develop marketable products that meet performance requirements while reducing risk associated with potential hazard and exposure attributes. While DfE does not assess performance considerations, these attributes are critical to the overall function and marketability of flame retardants.

9.2.4. Examples assessed by the criteria

Substance are chosen to apply in these considerations listed before, the result is shown in the following chart:

Table 9-4: Examples assessed by the criteria

Substance/considerations	Hazard Considerations criteria (inculdes human health hazard, ecotoxicity, persistence, bioaccumulation potential, potential for long-range environmental transport)	Social Considerations (occupational, consumer and lifestage, environmental justice)	Performance, Availability, Accessibility and Cost Considerations

EPS or XPS	Emerald 3000	Slightly irritating to skin; mildly irritating to the eyes (Chemtura MSDS 2013) Long-term aquatic toxicity not expected (Davis 2011)	No information available	Currently not commercially available Lack of information to access economic feasibility
	TBBPA bis (allyl ether)	Not bioaccumulative Inherently toxic to aquatic organisms with long lasting Persistence (USEPA ACToR) Causes serious eye irritation (ECHA C&L)	No information available	Likely to be commercially available and be economically feasible
	Dibromoethyl dibromocyclo hexane	Not inherently toxic to aquatic organisms (USEPA ACToR) Causes serious eye irritation (ECHA C&L)	Technically feasible	commercially available, Likely to be economically feasible
	Non-flame retarded EPS and XPS with thermal barriers	Concrete(a thermal barrier) contains trace amount of known human carcinogens (IARC 2013) Eye contact with wet concrete can cause moderate eye irritation, chemical burns and blindness; wet unhardened concrete and concrete dust may cause irritation, severe burns, and dermatitis (Chandler Concrete MSDS 2008)	Crystalline silica in concrete is a serious exposure concern for workers involved in concrete manufacturing and processing	commercially available Widely used in the EU and therefore assumed to be proven effective Lack of information on cost Concrete is associated with significant impacts on energy consumption, greenhouse gas emission, etc
HIPS	Resorcinol bis (biphenyl phosphate)	Toxic to aquatic life with long lasting effects Lack data to assess other hazard characteristics May cause mild irritation to the eyes (CCC Limited 2011)	Like to be technically feasible	Likely to be economically feasible Likely to be commercially feasible
	Bisphenol A bis (biphenyl phosphate)	May cause long lasting effects to aquatic life (ECHA C&L) Lack data to assess other hazard	Like to be technically feasible	Likely to be economically feasible Likely to be commercially

		characteristics		feasible
	Diphenylcresyl phosphate	May impair fertility and cause damage to organs Very toxic to aquatic life with long lasting effects Moderately irritating (patch test) (TOXNET HSDB)	Like to be technically feasible	Likely to be economically feasible Likely to be commercially feasible
	,Triphenyl phosphatean d alloys of PPE/HIPS treated with halogen-free flame retardant alternatives.	Persistent(CCR)	Technically feasible(used by major European TV set manufacturers)	Commercially available Probably economically feasible(currently being used in the commercial market)
Textile back coating	Intumescent systems containing ammonium polyphosphate,pentaerythritol and melamine	Melamine causes severe skin burns and eye damage; may cause allergic skin reaction; may cause damage to organs and is very toxic to aquatic life with long lasting effects Ammonium polyphosphate is persistent and inherently toxic to aquatic organisms (USEPA ACToR OECD SIDS(a))	Likely to be technically feasible	Likely to be economically feasible and commercially feasible(have been on the market for about 20 years) Require special handling during application to ensure desired performance

9.3 Examples of alternatives for HBCD

9.3.1. Alternatives for HBCD in HIPS

With respect to PPE/HIPS, major European manufactures of television sets appear to be using alloys including PPE/HIPS with non-halogenated flame retardant. This is an indication that alloys of PPE/HIPS with non-halogenated flame retardant also perform to required industry standards. Alloys of PPE/HIPS are known to have relatively higher inherent resistance to burning and spreading fire because they form an insulating char foam surface when heated. They also have higher impact strength and give similar design opportunities for parts with fine structural details. In addition, alloys of PPE/HIPS require fewer changes to the expensive molds and tooling used in the molding process (Maag et al. 2010).

9.3.2. Butadiene styrene brominated copolymer

Based on DfE AA criteria and guidance, the hazard profile of the butadiene styrene brominated copolymer (CASRN 1195978-93-8) shows that this chemical is anticipated to be safer than HBCD for multiple endpoints. Due to its large size, lack of low molecular weight (MW) components, and un-reactive functional groups, human health and ecotoxicity hazard for this polymer are measured or predicted to be low, although experimental data were not available for all endpoints. In general the exposure potential to the butadiene styrene brominated copolymer is expected to be lower than the other chemicals in this assessment because it is a large polymer and is unlikely to be released from the polystyrene. However, this alternative is inherently persistent and its long-term behaviour in the environment is not currently known. Chemical suppliers have commercialized this polymer, and polystyrene manufacturers are testing it in their products to ensure that the polystyrene will meet all performance standards. The hazard designations for this alternative are based upon high MW formulations of the polymer, where all components have a MW >1,000. The polymer is regulated with a Significant New Use Rule that was finalized in June 2013. Manufacture (or import) of the polymer requires notification to EPA except in these cases: (1) the MW of the polymer is in the range of 1,000 to 10,000 daltons, or (2) the MW of the polymer is ≥10,000 daltons and less than 5 percent of the particles are in the respirable range of 10 microns or less (U.S. EPA 2013).

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ANNEXES

ANNEX A. Sampling HBCD presence and concentration tests

For Tier III assessment some sampling and analysis might be necessary (see chapter 5 and chapter 7). As mentioned in chapter 5, HBCD has been the only flame retardant used in EPS and XPS until recently. Therefore all EPS and XPS tested bromine positive which have been produced before 2014 contain most likely HBCD which can be utilized in a screening of HBCD in lame retarded EPS and XPS.

For a useful and robust monitoring, a detailed sampling plan and a reliable instrumental analysis including standardized clean-up procedures are necessary. In this Annex some basic conditions are compiled for a fist orientation. More details on screening of POPs in articles can be found in the *Draft Guidance on Sampling, Screening and Analysis of Persistent Organic Pollutants in Products and Articles* (Secretariat of the Stockholm Convention 2013).

A2.1. Sampling

The overall objective of any sampling activity is to obtain a sample which can be used for the targeted purpose, e.g., characterisation of the overall presence of HBCD in an application, presence of HBCD in recycling materials, site characterization and compliance with regulatory standards or suitability for proposed treatment or disposal. This objective should be identified before sampling is started. It is indispensable for quality requirements in terms of equipment, transportation and traceability to be met.

Standard sampling procedures should be established and agreed upon before the start of the sampling campaign. Elements of these procedures include the following:

a) The number of samples to be taken, the sampling frequency, the overall duration of the sampling project and a description of the sampling method (including quality assurance procedures put in place, e.g., appropriate sampling containers, field blanks and chain-of-custody);

b) Selection of location or sites and time of sample-taking (including description and geographic localization);

c) Identity of person who took the sample and conditions during sampling;

d) Full description of sample characteristics

e) Labelling which gives detailed information or a specific sample code and can not be removed easily;

f) Preservation of the integrity of samples during transport and storage (before analysis);

g) Close cooperation between the sampler and the analytical laboratory; and

h) Appropriately trained sampling personnel.

Sampling should comply with specific national legislation, where it exists, or with international regulations. In countries where regulations do not exist, qualified staff should be appointed. Sampling procedures include the following:

a) Development of a standard operational procedure (SOP) for sampling each of the matrices for subsequent analysis;

b) Application of well-established sampling procedures such as those developed by the International Organization for Standardization (ISO), the European Committee for Standardization (CEN), the United

States Environmental Protection Agency (USEPA), the Global Environment Monitoring System (GEMS) or the American Society for Testing and Materials (ASTM); **however since for the analysis of HBCD in polystyrene or textiles no standard has been developed currently in-house methods need to be used. These methods should be described in respective monitoring reports.**

c) Establishment of quality assurance and quality control (QA/QC) procedures.

All these steps should be followed if a sampling programme is to be successful. Similarly, documentation should be thorough and rigorous.

A2.2. Screening of Bromine as indication for HBCD[22]

The screening of bromine can be a simple, rapid and cost-effective method for pre-selection steps of samples to determine which samples to select for the more complex and expensive confirmation analysis (see below). Since HBCD has been the only flame retardant used in EPS and XPS until recently, all EPS and XPS tested bromine positive which have been produced before 2014 contain most likely HBCD. Therefore bromine screening can be used for a screening of HBCD in EPS and XPS. In textiles also PBDE and other brominated flame retardants are use in addition to HBCD (see e.g. Kajiwara et al. 2014 in monitoring of textiles in cars). Therefore for textiles bromine positive samples need a further confirmation analysis to determine the used flame retardant. Since also PBDE are listed as POPs a bromine positive textile sample might indicate the presence of POPs (see e.g. Kajiwara et al. 2014).

A range of technologies can be used for screening bromine in materials like plastics, polystyrene (PS) or polyurethane (PUR) foams, textile or rubber. Technologies used include X-ray fluorescence (XRF), Sliding Spark Spectroscopy (Seidel et al. 1993), X-ray transmission (XRT) or Laser-Induced Breakdown Spectrometry (LIBS) (Stepputat & Noll 2003).

The X-ray fluorescence (XRF) technology is the most widely used screening technology in the field. In recent years several developing countries have purchased XRF instruments in the frame of the NIP update. The technology can be used for detection of bromine in polymers and other materials with a detection limit for bromine of 10 to 100 ppm. XRF analysis is limited to the detection of bromine in the material, without any capacity to identify the type of BFR compound. Using handheld instruments the time requirement for a measurement is less then a minute. Precision of XRF screening measurements is limited and thus relative standard deviations of up to 30% may be obtained. However, this is only critical when measuring levels very close to a given threshold.

Care has to be taken with screening methods if the plastic or other material is coated. Then the coatings might need to be removed by scratching. Also dirt should be removed for an optimized screening. If a sample his heterogeneous (e.g. waste EPS/XPS) then the different samples or parts need to be screened. Also in the analysis of EPS buoy within the same buoy the HBCD concentration should a variation and the levels were relatively low (Hong et al. 2013) indicating that is has been produced from recycled EPS and that in this process then the HBCD might be inhomogeneously distributed in an article.

XRF is a non-destructive method and can, therefore, be used to screen articles in stores or currently in use without damaging them.

The use of XRF instrument requires a specific instruction for the operator of handling such materials according to national guidelines. XRF with different X-ray source are available. Some of the XRF systems use a ^{63}Ni X-ray source and therefore a radioactive element. These equipments require special waste management at the end

[22] For more detail see *Draft Guidance on Sampling, Screening and Analysis of Persistent Organic Pollutants in Products and Articles* (Stockholm Convention Secretariat 2013)

of the product's lifetime.
Also non-radioactive instruments need careful operation and the personal using the equipment need to be trained for the specific equipment used. Several systems are commercially available.
The use area of these XRF instruments is much broader than bromine and chlorine screening. Such instruments can e.g. be used for screening of heavy metals and other elements in consumer goods or contaminated soils.

A2.3. Laboratory Analysis

Analysis refers to the extraction, purification, separation, identification, quantification and reporting of POP-PBDEs and/or HBCD concentrations in the matrix of interest. In order to obtain meaningful and acceptable results, the analytical laboratory should have the necessary infrastructure (housing) and proven experience.

Accreditation of the laboratory according to ISO 17025 or other standards by an independent body is also important. Essential criteria for obtaining high-quality results include:

(a) Specification of the analytical technique;

(b) Maintenance of analytical equipment;

(c) Validation of all methods used (including in-house methods); and

(d) Training of laboratory staff.

Extraction and cleanup is performed to isolate the HBCD from the co-extracted interfering compounds. A reliable analysis of HBCD/BFRs in polymers necessitates an efficient sample extraction process of the additives from the matrix. Extraction is the term given to the process of isolating specific compounds from a bulk matrix. The most relevant matrix for monitoring HBCD in articles are polymer samples since the majority of HBCD was used in EPS and XPS (see chapter 2). Also the only exempted use for HBCD is EPS/XPS in construction for insulation[23]. Extraction methods of HBCD from polymers (such as EPS or XPS) have been developed and provide an appropriate base for the monitoring of HBCD in articles and products. For the determination of additive BFRs in polymeric materials, solvent extraction plays an important role in the overall procedure. There are two main approaches for extracting HBCD from polymers: A) solid-liquid extraction and B) dissolution/precipitation. The solid-liquid approach extracts HBCD/BFR from ground solid plastics and is applicable, when there is no or only a minor dissolution of solvent and polymer, since partly dissolved polymers contaminate the GC-MS system (if not completely removed in the clean-up).

The dissolution/precipitation approach dissolves both, polymeric matrix and POP-PBDE/BFR and the dissolved polymer is removed in a second precipitation step (Secretariat of the Stockholm Convention 2013. Dissolution of plastics is also described in further detail by Braun (1999).

For the analysis of HBCD in other matrices such as soil, water or sediment no international standard method are available, but some research institutions have developed a number of analysis methods of HBCD in these environmental media. For environmental samples such as soil, sediments and dust recently a simple one-step extraction/clean-up method for determination of HBCDs, PCBs and PBDEs in environmental solid matrices (Abdallah et al. 2013).

[23] United Nations (2013) SC-6/13: Listing of hexabromocyclododecane. Reference: C.N.934.2013.Treaties-XXVII.15 (Depositary Notificatification). (decision SC-6/13)

For biota and food samples co-extracted lipids can be removed by e.g. gel permeation chromatography (GPC), alumina-oxide chromatography and (multilayer) silica chromatography (Covaci et al. 2007).

The next step is fractionation to isolate the HBCD from other pollutants and potentially interfering compounds. This is typically done by silica column fractionation (Covaci et al. 2007). β-HBCD requires more solvent than α- and γ-HBCD for a complete elution from a silica column (Morris et al. 2006; Mariussen et al. 2010). Care has to be taken in the clean-up of HBCD. E.g. silica treated with alcoholic NaOH or KOH may cause losses of HBCD due to the loss of hydrogen bromide (Covaci et al., 2007; de Boer et al., 2001), leading to one or more unsaturations in the HBCD stereoisomers.

Current analytical methods allow the chromatographic separation and determination of all HBCD stereoisomers (α- to ε-HBCD). These methods are based on reversed phase liquid chromatography (LC). LC based separation methods of chiral compounds allow analysis of HBCD enantiomers. HBCD can also be determined by gas chromatography (GC), but the separation of stereoisomers is not possible by this approach. Also HBCD can degrade on the GC column if too high temperatures are applied in the analysis (e.g. injector block) or if long GC-columns are used (see below).

Depending on the method used, the concentration is either reported as total HBCD (GC) or as results for the individual α-, β- and γ-HBCD stereoisomers, and the sum thereof (LC). The analytical method starts with the extraction of the HBCD from the sample. Several methods for extraction of biological samples have been proposed in the literature as reviewed by Covaci et al. (2007). For extraction of solid material, the Soxhlet procedure is used in some laboratories because it is simple and provides high extraction efficiency. Other techniques include pressurised liquid extraction (PLE), shaking with organic solvent (Nakagawa et al., 2010) and solid-phase extraction (SPE).

HBCD can be analysed by GC-MS methods. The injection of HBCD into the GC system is a critical part of the chromatographic analysis. Splitless injection is the most commonly used technique for GC analysis of HBCD. However, the programmable temperature vaporisation injector (PTV) and on-column injectors have also been used successfully in HBCD GC analysis. At temperatures >190°C, the ratio between the HBCD stereoisomers may change (Peled et al., 1995) as discussed in an analytical chemical perspective (Covaci et al., 2003; de Boer and Wells, 2006) and at >240°C HBCD decompose to many different compounds (Morris et al., 2006; Barontini et al., 2001). Therefore, long sample residence times at high temperatures in the injector should be avoided.

GC separations are done on capillary columns with a non-polar or slightly polar stationary phase. The column dimensions should be kept short (less than 30 m length; normally 0.25 mm diameter and 0.1-0.25 µm film thickness). HBCD may degrade in the GC column to pentabromocyclododecene and tetrabromocyclododecadiene (Abdallah et al 2008; van Leeuwen 2009). In particular, the degradation of HBCD is increased by e.g. high temperatures, time spent at elevated temperatures and presence of catalytic sites when GC analysis is applied. For the best yield of HBCD, these parameters should be controlled.

In GC-low resolution MS (LRMS), electron chemical negative ionisation (ECNI) is commonly used as ionisation method for BFRs. This ionisation method provides significantly better sensitivity compared to electron impact (EI) ionization, although at the cost of selectivity (Covaci et al. 2006, 2007). With ECNI-MS, only the bromine isotopes (m/z 79 and 81) are monitored which hampers the identification of different compounds based on their molecular masses. With EI the [M-Br]- ion can be monitored resulting in higher selectivity (Roosens et al. 2008). The latter provides the possibility to use mass labelled standards, but the sensitivity is too low for many environmental samples in the case of LRMS. The analysis of total-HBCD can also be performed by integrating it into the method for the determination of PBDEs applying GC-high resolution MS (GC-HRMS) (Shaw et al. 2008).

MS responses differ for α-, β- and γ-HBCD stereoisomers, with α-HBCD showing the highest response. Because of this difference, it is essential that the stereoisomer profile in the calibration solution is equal to the profile in the analysed sample.

For the analysis of the HBCD stereoisomers, generally reversed phase columns are being used and for the analysis of the enantiomers, enantioselective columns (permethylated-cyclodextrin stationary phases) are required (Janak et al., 2005; Marvin et al., 2007). Enantioselective analysis allows determination of enantiomers and can detect whether enrichment of (+) or (-) enantiomers occurs. For example, Eljarrat et al. 2009) found (-)-α-HBCD to dominate in human milk samples.

LC-MS detection is mostly performed on triple-quadrupole instruments (MS/MS) using the electrospray ionisation (ESI) source. ESI-ion trap MS instruments (ITMS) have been used as well as atmospheric pressure chemical ionisation (APCI). For an extensive overview of methods used see Covaci et al. (2007). ESI was preferred over APCI by Budakowski and Tomy (2003). In the ESI source, the formation of [M-H]- takes place. The MS spectrum exhibits bromine clusters because of the two bromine isotopes m/z 79 and m/z 81 present. The most intense peak in the cluster is m/z 640.7 (12C12H17 79Br3 81Br3). Triple quadrupole MS/MS instruments allow for selective detection by isolation of the precursor ion [M-H]- (m/z 640.6) in the first quadrupole, followed by detection of the bromine isotope [Br]- (m/z 79 and/or 81) in the third quadrupole.

A major advantage of LC-ESI-MS (/MS) and GC-EI-HRMS over GC-ECNI-MS is the option of using 13C labelled internal standards. These standards allow correction for losses during extraction and clean-up. Furthermore, several studies showed that these labelled standards effectively correct for matrix suppression or enhancement occurring in the ESI source (Tomy et al., 2005; Gómara et al., 2007; Marvin et al., 2007).

The results obtained by both techniques for fish samples showed large discrepancies in a study by van Leeuwen and de Boer (2008). GC results were on average 4.4-fold higher than LC results.

Discrepancies between GC and several LC methods were also found by Roosens et al. (2008) in eel samples. On the other hand, Päpke et al. (2010) reported on the analysis of food samples by GC-ECNI-MS and LC-MS/MS and found a close agreement between both techniques.

ANNEX B. QUESTIONNAIRE

ANNEX B.1 QUESTIONNAIRE for compiling information on the presence of hexabromocyclododecane HBCD in Extended Polystyrene (EPS) and Extruded Polystyrene (XPS) in insulation in construction, packaging and other uses and related recycling and waste

1) Background information

In May 2013, hexabromocyclododecane (HBCD) was listed in the Stockholm Convention as persistent organic pollutants (POPs) in Annex A, with specific exemption in insulation in construction[24]. Since November 2014 the listing of HBCD to the Stockholm Convention entered into force for most parties[25].

Parties to the Convention for which the amendments have entered into force have to meet the obligations under the Convention to eliminate HBCD for the production and uses not exempted.

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.

To develop effective strategies to eliminate HBCD, Parties need to acquire a sound understanding of their national situation. Such information can be obtained through an inventory of HBCD in different uses.

Extended Polystyrene (EPS) and Extruded Polystyrene (XPS) were the major uses of HBCD in the world market. Only flame retarded EPS contains HBCD. The use of HBCD in XPS and EPS depends on the application and on the region. E.g. in Western Europe approximately 70 % of the EPS is flame retarded while in East Europe about 99% (Seppälä 2013)[26]. The major use of HBCD was in EPS and XPS in the construction sector (see chapter 2 of this HBCD inventory guidance). However not all EPS and XPS in the construction sector contain HBCD. Recently also alternative flame retardants are available for EPS/XPS. EPS/XPS packaging is normally not treated with HBCD. However initial screening have revealed that at least in some countries packaging including food packaging can contain HBCD (Rani et al. 2014)[27].

2) Aim of the questionnaire

This questionnaire is aimed at gathering information on the current and former use of HBCD in insulation in buildings and construction as well as in possible use in packaging and other uses.
This information will be very valuable in order to assess the current situation and will constitute the basis for the country to manage HBCD and related treated materials within the update of the National Implementation Plan of the country.

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[24] United Nations (2013) SC-6/13: Listing of hexabromocyclododecane. Reference: C.N.934.2013.Treaties-XXVII.15 (Depositary Notificatification). (decision SC-6/13)

[25] 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. Also, 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 with paragraph 4 of Article 25.

[26] Listing hexabromocyclododecane in Annex A of Stockholm Convention Presentation. 12th HCH and Pesticide Forum, 6-8 November 2013, Kiev Ukraine.
http://www.hchforum.com/12th/presentations/pdf/2_Timo%20Seppala%20-%20HBCD%20in%20the%20Stockholm%20Convention.pdf

[27] Rani et al. (2014) HBCD in polystyrene based consumer products: an evidence of unregulated use. Chemosphere 110, 111-119.

1. Name and address of industry:

Name of industry/company or institution	Address

2. Type of company or industry:

☐ Production of EPS and XPS for construction ☐ Production of EPS and XPS for packaging
☐ Import of EPS and XPS for construction ☐ Import of EPS and XPS for packaging production
☐ Retail of EPS and XPS for construction ☐ Retail of EPS and XPS for packaging production
☐ Recycling of EPS and XPS from construction/packaging and other uses[28]
☐ Disposal of EPS and XPS from construction/packaging[29]
☐ Other uses of EPS/XPS (please specify):

3. Use of HBCD in EPS and XPS in different products and use (please see also table Q1 and Q2)

Was or Is HBCD currently used in EPS or XPS production and application? (Please fill details in table Q1/Q2 below)

Are you planning to further use HBCD in EPS or XPS applications? For which uses?

What alternatives are available for HBCD in XPS/EPS or alternatives to XPS/EPS in the country/region?

[28] Recycling of EPS and XPS is not exempted by the Stockholm Convention.

[29] EPS and XPS packaging is normally not treated with HBCD. However initial screening have reviled that at least in some countries packaging including food packaging can contain HBCD (Rani et al. 2014).

Table Q1: HBCD use in different EPS uses in construction and other uses and related volumes (current and past)

EPS Uses	HBCD content (%)	**Years of production and use (from and until)**	**Total volume of HBCD containing XPS (tonnes) (Total historic production/ Current production)**
EPS Flat roof insulation			**……………..t/…………………t**
EPS Pitched roof insulation			**……………..t/…………………t**
Floor insulation 'slab-on-ground' insulation			**……………..t/…………………t**
Insulated concrete floor systems			**……………..t/…………………t**
Interior wall insulation with gypsum board			**……………..t/…………………t**
Exterior wall insulation or ETICS (External Insulated Composite Systems)			**……………..t/…………………t**
Cavity wall insulation boards			**……………..t/…………………t**
Cavity wall insulation loose fill			**……………..t/…………………t**
Insulated concrete forms (ICF)			**……………..t/…………………t**
Foundation systems and other void forming systems			**……………..t/…………………t**
Load bearing foundation applications			**……………..t/…………………t**
Core material for EPS used in sandwich and stressed skin panels (metal/wood fibreboard)			**……………..t/…………………t**
Floor heating systems			**……………..t/…………………t**
Sound insulation in floating floors (to avoid transmission of contact sound)			**……………..t/…………………t**
EPS drainage boards			**……………..t/…………………t**
EPS concrete bricks, EPS concrete			**……………..t/…………………t**
EPS Soil stability foam (civil engineering use)			**……………..t/…………………t**
EPS Seismic insulation			**……………..t/…………………t**
EPS Packaging materials made of PS foams*			**……………..t/…………………t**
Other molded EPS articles, such as ornaments, decorations, logos, etc.			**……………..t/…………………t**
Other EPS application (please specify):			**……………..t/…………………t** **……………..t/…………………t**

Table Q2: HBCD use in different XPS uses in construction and other uses and related volumes (current and past)

XPS Use	HBCD content (%)	Years of production and use (from and until)	Total volume of HBCD containing XPS (tonnes) (Total historic production/ Current production)
Cold bridge insulation			……………..t/…………………t
Floors			……………..t/…………………t
Basement walls and foundations			……………..t/…………………t
Inverted roofs			……………..t/…………………t
Ceilings			……………..t/…………………t
Cavity insulation			……………..t/…………………t
Composite panels and laminates			……………..t/…………………t
Food packaging			……………..t/…………………t
Other uses: (please specify)			
			……………..t/…………………t
			……………..t/…………………t

4. EPS and XPS in recycling and related products HBCD containing materials and waste wastechemical/formulation and HBCD containing EPS or XPS

EPS and XPS can be recycled. The recycling of HBCD containing EPS and XPS is not allowed in the Convention. If the HBCD concentration is below the low POPs limit[30] recycling might be allowed. In the following table information on EPS/XPS recycled, the related HBCD content and the final products will be listed.

EPS/XPS materials used in recyling (tonnes)	HBCD present or absent and content (ppm)	Products made from recycling (tonnes) Related HBCD content (ppm)	Waste generated during recycling (tonnes) Related HBCD content (ppm)

[30] The low POPs limit for HBCD has not yet been determined within Basel/Stockholm Convention.

5. HBCD containing EPS/XPS waste (from production and end of life) and related management?[31] (Please use separate sheet if necessary to document all information)

Type of waste/stockpile	**Stockpile** **- total volume (tonnes)** **- HBCD content (%)** **- address/location** **- Condition of stockpile**	**Waste treatment (please specify),** **A. destroyed in waste treatment facility,** **B. Sent to landfill , C. others (also specify)** **(including addresses)**
(a) HBCD as chemical: **(i) Pure HBCD;** **(ii) Obsolete HBCD, which can no longer be used;**		
(b) HBCD containing mixtures and articles: **(i) EPS beads;** **(ii) XPS masterbatch;** **(iii) EPS/XPS foam production waste (cutting waste, etc.);** **(iv) HBCD containing packing;**		
c) HBCD-containing waste from demolition: **(i) Construction and demolition waste (insulation boards used in foundation, walls and ceilings, ground deck, parking deck, etc.);**		
d) HBCD-containing other wastes **(i) Packaging materials made of PS foams;** **(ii) Ornaments and decorations;** **(iii) EPS loose filling used in furniture (bean bags, sofas etc);**		

[31] For the environmental sound management of HBCD containing waste see the *Draft Technical guidelines for the environmentally sound management of wastes consisting of, containing or contaminated with commercial octabromodiphenyl ether (hexabromodiphenyl ether and heptabromodiphenyl ether), commercial pentabromodiphenyl ether (tetrabromodiphenyl ether and pentabromodiphenyl ether) and hexabromocyclododecane* (Secretariat of the Basel Convention 2014).

6. Locations contaminated or possibly contaminated with HBCD or EPS/XPS containing HBCD (Please see chapter 8 of the HBCD inventory guidance)

Location/address	Type of contamination	Type of activity at the location	Have the site been investigated?	Levels of HBCD (if available)

7. Further Remarks

8. Information on respondent

Name	
Department	
Position	
Telephone	
Mobile Phone	
Email Address	
Signature	
Date	

Please consider the environment and health when selecting chemicals in production and in products

ANNEX B.2 QUESTIONNAIRE for compiling information on the presence of HBCD in textile application and related recycling and waste

1) Background information

In May 2013, HBCD was listed in the Stockholm Convention as persistent organic pollutants (POPs) in Annex A, with specific exemption in insulation in construction[32]. Since November 2014 the listing of HBCD to the Stockholm Convention entered into force for most parties[33].

Parties to the Convention for which the amendments have entered into force have to meet the obligations under the Convention to eliminate HBCD for the production and uses not exempted.

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.

To develop effective strategies to eliminate HBCD, Parties need to acquire a sound understanding of their national situation. Such information can be obtained through an inventory of HBCD in different uses.

Extended Polystyrene (EPS) and Extruded Polystyrene (XPS) were the major uses of HBCD in the world market.

The second most important application is in polymer dispersion on cotton or cotton mixed with synthetic blends or synthetic, in the back-coating of textiles (UNEP 2010). The HBCD use in textile is not exempted from Stockholm Convention provisions. Therefore the use of HBCD in this application need to be stopped and the treated textiles are not allowed to be recycled.

2) Aim of this questionnaire

This questionnaire is aimed at gathering information on the current and former use of hexabromocyclododecane (HBCD) in textiles. This include flame retarded textiles in the transport sector, flame retarded textiles in indoor use (e.g. curtains, furniture, mattress ticking) and flame retarded clothing (e.g. fire fighter uniform; military uniform; sleep wear). It needs to be emphasizes that only some of flame retarded textiles in these use sector contain HBCD and also materials can be used which do not need addition of flame retardants. Furthermore the use of flame retardants depend also on the flammability standards in a country.

The information on current and former use of HBCD in the textile sector will be very valuable in order to assess the current situation in these uses sector and will constitute the basis for the country to manage HBCD and related treated materials within the update of the National Implementation Plan of the country.

[32] United Nations (2013) SC-6/13: Listing of hexabromocyclododecane. Reference: C.N.934.2013.Treaties-XXVII.15 (Depositary Notificatification). (decision SC-6/13)

[33] 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. Also, 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 with paragraph 4 of Article 25.

1. Name and address of the flame retarded textile producer, user or (major) retailer:

Name	Address

2. Select the type of activity of your textile business or textile use that apply

Manufacturing of textiles in transport seating and other textile/synthetics in transport sector[34]	☐	Manufacturing of textiles applications used indoor[35]	☐
Manufacturing of flame retarded textile clothing[36]	☐	Import of textiles in transport seating and other textile/synthetics in transport sector[34]	☐
Import of flame retarded textile applications used indoor[35]	☐	Import of flame retarded textile clothing[36]	☐
Retail sale of textiles in transport seating and other textile/synthetics for transport sector[34]	☐	Retail sale of flame retarded textiles applications used indoor[35]	☐
Retail sail of flame retarded textile clothing[36]	☐	Recycler of possibly flame textiles from transport sector[34], flame retarded textiles applications used indoor[35], flame retarded textile clothing[36]	☐
Disposal of textiles in transport seating and other textile/synthetics in transport sector[34], textiles applications used indoor[35], textiles clothing[36]	☐	Others (Please specify):	☐

3. Indicate the type of textiles you deal with

Textiles for transport seating and other textile/synthetics in transport sector[37]	☐	Flame retarded textiles applications used indoor[35]	☐
Flame retarded clothing[36]	☐	Textiles for recycling to produce other products	☐
Flame retarded textiles for disposal	☐	Others (Please specify):	☐

[34] Flame retarded textiles in transport might be used in seating, floorcoverings, roof-lining fabrics and other furnishings within the vehicle or vessel interior (see Guidance for the inventory, identification and substitution of Hexabromocyclododecane (HBCD) see chapter 6 (Secretariat of the Stockholm Convention 2015).

[35] This might include curtains, textile upholstery of furniture, bed mattress ticking, wall coverings and draperies (UNEP (2010). Risk profile on hexabromocyclododecane. UNEP/POPS/POPRC.6/13/Add.2; Horrocks 2013).

[36] In particular specific personal protective equipment (PPE) clothing (e.g. for fire fighter and military uniform; other technical textiles, sleep wear) can contain HBCD or other flame retardants.

[37] Flame retarded textiles in transport might be used in seating, floorcoverings, roof-lining fabrics and other furnishings within the vehicle or vessel interior (see Guidance for the inventory, identification and substitution of Hexabromocyclododecane (HBCD) chapter 6 (Secretariat of the Stockholm Convention 2015).

3. Current and past use of HBCD in flame retarded textile applications (please see table Q3 on next page)

Was or Is HBCD currently used in your textile production, use or sale? (Please fill details in table Q3 below)

Are there particular flammability standards requiring the use of flame retardants (for which textile applications)?

Are you aware that the use of HBCD in textile will be phased out? When have you stopped producing or using HBCD in textiles or when are you planning to stop the use of HBCD?

What alternative chemicals are used for impregnation or coating of textiles? You might fill in the information available from safety data sheets or suppliers/producers.

Name of chemical or mixtures	Product code or number/ CAS number	Use on what type of textile for which product	Weight ratio applied
			[wt%]
			[wt%]
			[wt%]
			[wt%]

Table Q3: (Former) HBCD use in different flame retarded textile application, related content and textile volumes

Flame retarded textile uses	HBCD content (%)	Years of production and use (from and until)	Total volume of HBCD containing textiles (tonnes) (Total historic production/ Current production)
Textiles used in upholstery in vehicles (cars, busses, trucks) (please specify)			……………..t/…………………t
Textiles used in user transport (trains, air planes, ships) (please specify)			……………..t/…………………t
Textiles used in upholstery furniture			……………..t/…………………t
Mattress ticking			……………..t/…………………t
Textiles used in roller blinds			……………..t/…………………t
Other flame retarded textiles used indoor (please specify)			……………..t/…………………t
			……………..t/…………………t
Fire fighter uniform			……………..t/…………………t
Flame retarded military uniform			……………..t/…………………t
Flame retarded sleepwear			……………..t/…………………t
Other flame retarded clothing (please specify)			……………..t/…………………t
			……………..t/…………………t
			……………..t/…………………t

Other related information and comments:

4. HBCD containing textile stockpiles and waste (from production and end of life) and related management[38] (Please use separate sheet if necessary to document all information)

Type of waste/stockpile	Stockpile - total volume (tonnes) - HBCD content (%) - address/location - Condition of stockpiles	Waste treatment (please specify including addresses of facilities) A. destroyed in waste treatment facility, B Sent to landfill, C. others (also specify).
(a) Textiles for/from transport Light shredder residues from transport sector (cars, busses, trucks) containing textiles and polymers; Textiles from other transport (trains, air planes, ships)		
(b) Treated Textiles for/from indoor uses (curtains, roller blinds; textiles from furniture upholstery)		
c) Mattress ticking		
d) Flame retarded clothing - Fire fighter uniform - Military uniform - Sleep wear		

Other related information and comments:

[38] For the environmental sound management of HBCD containing waste see the *Draft Technical guidelines for the environmentally sound management of wastes consisting of, containing or contaminated with commercial octabromodiphenyl ether (hexabromodiphenyl ether and heptabromodiphenyl ether), commercial pentabromodiphenyl ether (tetrabromodiphenyl ether and pentabromodiphenyl ether) and hexabromocyclododecane* (Secretariat of the Basel Convention 2014)

5. Locations contaminated or possibly contaminated with HBCD or EPS/XPS containing HBCD (Please see chapter 8 of the HBCD inventory guidance)

Location/address	**Type of contamination**	**Type of activity at the location**	**Have the site been investigated?**	**Levels of HBCD (if available)**

6. If you are a supplier/producer or downstream user of HBCD in textiles please name the company you sell to or buy from (indicate respective):

Name of company	Product	Contact information

7. Please specify the suppliers/producers of the HBCD containing mixtures/materials used

Name of company	Product	Contact information

8. Other remarks from your side

9. Respondent

Name	
Department	
Position	
Telephone	
Mobile Phone	
Email Address	
Signature	
Date	

Please consider the environment & health when selecting chemicals in production and in products