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STOCKHOLM CONVENTION

GUIDANCE ON PREPARING INVENTORIES OF HBCD

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STOCKHOLM CONVENTION

Guidance on preparing inventories of hexabromocyclododecane (HBCD)

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Secretariat of the Basel, Rotterdam and Stockholm Conventions

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Abbreviations and acronyms

BAT/BEP	Best available technologies/best environmental practices
BFR	Brominated flame retardant
c-PentaBDE	Commercial pentabromodiphenyl ether
c-OctaBDE	Commercial octabromodiphenyl ether
COP	Conference of Parties
DecaBDE	Decabromodiphenyl ether
EEE	Electrical and electronic equipment
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
NGOs	Non-governmental organization
NIP	National implementation plan
PBDDs	Polybrominated dibenzo-p-dioxins
PBDEs	Polybrominated diphenyl ethers
PBDF	Polybrominated dibenzofurans
PCBs	Polychlorinated biphenyls
PCNs	Polychlorinated naphthalenes
PCP	Pentachlorophenol
POPs	Persistent organic pollutants
POP-PBDEs	Polybrominated diphenyl ethers listed in the Stockholm Convention
SC	Stockholm Convention
SCCPs	Short chain chlorinated paraffins
WEEE	Waste electrical and electronic equipment
XRF	X-ray fluorescence
XPS	Extruded polystyrene

1. Introduction to the guidance document

1.1 Hexabromocyclododecane (HBCD) in the Convention

HBCD is a brominated flame retardant used as an additive in polymer applications, providing fire protection during the service life of vehicles, buildings or articles, as well as protection while stored. 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.

In May 2013, the Conference of the Parties of the Stockholm Convention on Persistent Organic Pollutants (POPs) added hexabromocyclododecane (HBCD) to Annex A, with specific exemption for the production and use of HBCD for expanded polystyrene (EPS) and extruded polystyrene (XPS) in buildings (decision SC-6/13; United Nations, 2013). Parties 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. Pursuant to paragraph 4 of Article 21 of the Convention, the amendment entered into force for most parties on 26 November 2014[1].

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 that are not covered by the exemption. Each Party that has registered for the exemption pursuant to Article 4 shall, as per Part VII of Annex A, 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.

More information on the chemical properties, environmental fate, monitoring data, environmental and health risks of HBCD can be found in the risk profile (UNEP/POPS/POPRC.6/13/Add.2) (UNEP, 2010a) adopted by the POPs Review Committee of the Stockholm Convention in 2010.[2] Information on global production and uses of HBCD can also be found in risk management evaluation on hexabromocyclododecane (UNEP/POPS/POPRC.7/19/Add.1) (UNEP, 2011) and addendum to the risk management evaluation on hexabromocyclododecane (UNEP/POPS/POPRC.8/16/Add.3) (UNEP, 2012).

1.2 Purpose of the guidance

The purpose of this document is to provide Parties with guidance on the establishment of inventories of HBCD. The target audience is national focal points of the Convention and those involved in the process for NIP review and update, in particular the task teams and coordinators responsible for establishing the inventory.

In accordance with paragraph 1 (c) of Article 7 of the Convention, Parties are to review and update their national implementation plans (NIPs) and transmit it to the COP within two years of the date in which the amendment entered into force - in November 2016, for most Parties.

In accordance with Article 15 of the Convention, Parties are required to report to the Conference of the Parties on the measures they have taken to implement the provisions of the Convention and on the effectiveness of such measures in meeting the objectives of the Convention. This information includes statistical data on its total quantities of production, import and export of each of the chemicals listed in Annex A and Annex B or a reasonable estimate of such data. Article 6, paragraph 1 (a) of the Stockholm Convention requires each Party to develop appropriate strategies for the identification of products and articles in use and wastes consisting of, containing or contaminated with POPs. Information obtained through an inventory of HBCD may assist in meeting these obligations.

For more information, please consult *General guidance on POPs inventory development* (UNEP/POPS/COP.9/INF/19/Add.1) (UNEP, 2019).

[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.

[2] http://chm.pops.int/tabid/243/Default.aspx.

1.3 Other guidance documents to be consulted

The users of this guidance should also consult *General guidance on POPs inventory development* (UNEP/POPS/COP.9/INF/19/Add.1) (UNEP, 2019) and other guidance documents to support review and updating of national implementation plans available on the website of the Stockholm Convention[3], including the following:

- Risk profile on hexabromocyclododecane (UNEP/POPS/POPRC.6/13/Add.2) (UNEP, 2010a);
- Risk management evaluation on hexabromocyclododecane (UNEP/POPS/POPRC.7/19/Add.1) (UNEP, 2011);
- Addendum to the risk management evaluation on hexabromocyclododecane (UNEP/POPS/POPRC.8/16/Add.3) (UNEP, 2012);
- Draft guidance on best available techniques and best environmental practices for the production and use of hexabromocyclododecane listed with specific exemptions under the Stockholm Convention (UNEP/POPS/COP.8/INF/16) (UNEP, 2017c).

Furthermore, this document should be used in conjunction with documents developed under the Basel Convention which provide guidance on the development strategies and inventories in relation to POPs wastes including HBCD:

- General technical guidelines on the environmentally sound management of wastes consisting of, containing or contaminated with persistent organic pollutants (UNEP/CHW/COP.14/7/Add.1) (UNEP, 2018);
- Technical guidelines on the environmentally sound management of wastes consisting of, containing or contaminated with hexabromocyclododecane (UNEP/CHW.12/5/Add.7/Rev.1) (UNEP, 2015a);
- Methodological guide for the development of inventories of hazardous wastes and other wastes under the Basel Convention (UNEP/CHW/COP.12/9/Add.1) (UNEP, 2015b).

1.4 Objectives of the inventory

The national inventory on POPs provides information necessary for making decisions related to the management of POPs in accordance with the Stockholm Convention. More specifically, such an inventory can serve to:

- Provide the basis for the 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);
- Provide a basis for the evaluation whether the current national use, production, chemical and waste management meet the requirements of the Convention;
- Report to the Stockholm Convention COP on progress made to eliminate HBCD;
- Identify areas where financial or technical support is needed (when resources are limited, to fill the gaps in the inventory/fulfil the obligations of the Convention).

The information obtained in an inventory can include the following:

- Past and current uses/production of HBCD at the national level;
- Stockpiles;
- Presence of products and articles containing HBCD in 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;
- Management of HBCD containing waste (see UNEP, 2015a);
- Use of alternative flame retardants to HBCD (see UNEP/POPS/POPRC.8/16/Add.3) (UNEP, 2012);
- Potentially contaminated sites.

The inventory process may help the Party to assess the need for specific exemption for production or use of HBCD (see chapter 1.1). Information on the exemptions can be found on the website of the Convention. Information collected can also support reporting under Article 15.

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

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

2 How to develop an HBCD inventory

2.1 General guidance on POPs inventory development

Please refer to General guidance on POPs inventory development (UNEP/POPS/COP.9/INF/19/Add.1) (UNEP, 2019) for general approach to developing national inventories. The guidance describes general process to be taken in making an inventory. In summary, the following steps should be taken:

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

2.2 Step 1: Initiating the inventory development process

For general description of Step 1, please refer to Chapter 2.2 of General guidance on POPs inventory development (UNEP/POPS/COP.9/INF/19/Add.1) (UNEP, 2019).

In initiating the inventory development process, Parties are advised to establish a multi-stakeholder **national inventory team** for the task to ensure the necessary competences and access to the relevant inventory information. The inventory of HBCD can be combined with the inventory of other POPs (e.g. PBDEs) for synergies when investigating same sectors or activities (i.e. WEEE plastic, transport sector, construction, furniture and textiles).

To **define the scope of the** inventory, the national inventory should identify which sectors (industries, products, articles) will be contacted for the information in the process. Development of a national inventory of products and articles containing HBCD requires cooperation with the relevant authorities as well as manufacturers, users, suppliers and retailers of HBCD and products and articles containing HBCD as a flame retardant. Since more than 90% of HBCD has been used in EPS/XPS with main use in construction sector, it is likely to be the priority inventory area. Potential sectors and stakeholders involved in the life-cycle of HBCD are listed in Table 1 below.

Table 1: Sectors and stakeholders involved in the life-cycle of HBCD.

Sectors	Stakeholders
For all uses	• Ministry of Environment, and/or Ministry responsible for waste management • Ministry of Industry, Ministry of Labour • NIP coordinator and steering committee • Basel Convention focal point (and stakeholders in Basel) • Customs authorities • Authorities in charge with fire safety requirements of e.g. buildings, vehicles, and textiles • Industry producing HBCD or importing/exporting HBCD • NGOs working on POPs
Production of HBCD	• Chemicals industry (in the few countries where HBCD production takes place)
Expanded Polystyrene (EPS) **Extruded Polystyrene (XPS) in construction and buildings and in packaging**	• Authorities in charge of construction requirements, such as building code, as well as packaging requirements (e.g. food packaging) • Industry producing EPS raw material (downstream users of HBCD) • Industry manufacturing flame retardant EPS and XPS articles (e.g. EPS and XPS insulation, ornaments, logos, packaging materials) • Construction industry (in particular related to use of insulation) • Packaging industry • Importers and exporters of EPS and XPS articles (including insulation, packaging materials) • Retailers of insulation boards and other construction materials made of EPS/XPS (ornaments etc.) • Importers and exporters of HBCD waste • Potential recyclers of HBCD containing articles/products • Other relevant stakeholders in the country (e.g. institutes educating construction professionals)
Polymer dispersion for textiles in treated applications	• Importers and exporters of flame-retardant textiles/associations • Retailers of flame-retardant textiles • Users of flame-retardant textiles: Construction industry (in particular related to upholstery), transportation industry • Other relevant stakeholders in the country (e.g. research groups working on textile material flows)
Other uses (HIPS, latex binders, adhesives and paints)	• Importers and exporters of electric and electronic appliances, adhesives and paints • Manufacturers of electric and electronic appliances, adhesives and paints • Retailers of electric and electronic appliances, adhesives and paints • Other relevant stakeholder in the country
Companies recycling HBCD containing materials	• Recyclers of construction materials and furniture • Recyclers of packaging EPS and XPS • Recyclers of WEEE
End-of-life treatment	• Waste management companies • Companies operating waste incinerators or co-processing waste for energy production • Landfill operators

The depth of the inventory needs to be further defined in the course of the inventory when information becomes available considering the available resources.

2.3 Step 2: Choosing data collection methodologies

There are a number of different approaches that have been used for gathering information for POPs inventories, i.e. indicative method, qualitative method and quantitative method. For more information on those methodologies, please refer to Chapter 2.3 of General guidance on POPs inventory development (UNEP/POPS/COP.9/INF/19/Add.1) (UNEP, 2019).

Questionnaires and interviews are valuable instruments for primary data collection in inventory programs. Based on contact and consultation meetings with stakeholders, questionnaires with explanatory notes can be developed and sent to the relevant stakeholders to gather the information needed to compile data for a Tier II or Tier III assessment. Questionnaires for HBCD producers, users, or companies importing or selling HBCD as well as products containing HBCD are available in Appendix 1 and 2 to the present guidance and can be modified and adjusted as needed.

Samples of products and articles can be purchased or requested during on-site inspections at factories, retailers, markets, in buildings possibly containing HBCD, recycling locations, and waste disposal/storage facilities.

2.4 Step 3: Collecting and compiling data

For general description of Step 3, please refer to Chapter 2.4 of General guidance on POPs inventory development (UNEP/POPS/COP.9/INF/19/Add.1) (UNEP, 2019).

An initial assessment **(Tier I)** is carried out to obtain an overview of the relevant uses and stakeholders to be contacted in the key sector under investigation. Tier I methods usually rely on available literature and statistics in combination with calculations based on already existing information, such as the risk profile (UNEP/POPS/POPRC.6/13/Add.2) (UNEP, 2010a), risk management evaluation (UNEP/POPS/POPRC.7/19/Add.1) (UNEP, 2011), and addendum to the risk management evaluation (UNEP/POPS/POPRC.8/16/Add.3) (UNEP, 2012) adopted by the POPs Review Committee.[4] Also Technical guidelines on the environmentally sound management of wastes consisting of, containing or contaminated with hexabromocyclododecane (UNEP/CHW.12/5/Add.7/Rev.1) (UNEP, 2015a) contain useful information for the initial assessment.

Main inventory (**Tier II**) will be carried to collect data on the most important sectors and uses through interviews and questionnaires to the national stakeholders, and further identify missing information.

If needed and resources are available, a more in-depth inventory (**Tier III**) can be initiated fill in the data gaps remaining after the main inventory.

2.4.1 Tier I: Initial assessment

The initial assessment generally relies on collecting existing information, desk studies, interviews etc. First priority is to get an overview of the present and historical use of HBCD and its life-cycle in the country. The team should collect the existing past and present national data on the import and use of HBCD and articles containing HBCD from major stakeholders and sources including (see Table 1):

- Relevant industries or industry associations (in particular EPS/XPS/insulation material manufacturers; construction; textile);
- Ministry of Industry;
- Authorities in charge of fire safety regulations an building code;
- Customs services, the National Bureau of Statistics;
- Published literature in scientific journals and other studies;
- Online research.

Expected outputs of the initial assessment include:

(a) A list of authorities relevant to the production, import, and use of HBCD;

(b) Past and present fire regulations related to buildings, insulation materials, and textiles.

(c) A list of producers, exporters, and importers of HBCD;

[4] http://chm.pops.int/tabid/243/Default.aspx.

(d) Initial information on production and import of HBCD in the country;

(e) A list of potential users of HBCD (see Table 1);

(f) Initial information on the uses of HBCD in the country. Production volumes, import and trade of HBCD including products and articles containing HBCD;

(g) List of products/articles on the consumer market that may contain HBCD;

(h) Estimates of service life of the products/articles containing HBCD;

(i) Initial information on waste management of articles that may contain HBCD;

(j) Compilation of information as basis for Tier II assessment and initial feedback from stakeholders.

Based on these data, the team should assess the relevance of defined scope and whether all relevant stakeholders have been involved.

2.4.2 Tier II: Main inventory

Tier II of the inventory focuses on the sectors found relevant in the initial assessment. New information is collected through surveys and site visits. Examples of questionnaires that could be used in contacting the stakeholders are available in Appendices 1 and 2 to the present guidance. When the number of stakeholders is small, personal communication may be most appropriate.

The inventory team should look for information taking into account the life-cycle of HBCD in the country, including:

- Production of HBCD;
- Industries currently and formerly using HBCD;
- Products and articles manufactured using HBCD such as: flame-retardant expanded and extruded polystyrene, polymer dispersion for flame retardant textiles and other uses;
- Products and articles containing HBCD in use such as: flame-retardant expanded and extruded polystyrene, polymer dispersion for flame retardant textiles and other uses;
- Service life of products and articles containing HBCD;
- Stockpiles and wastes from current and former production and use in industries (countries that have produced or used HBCD in industries);
- Recycling of products and articles containing HBCD, including the types of articles produced from recycling;
- HBCD in waste and how waste containing HBCD is managed;
- Sites/locations where activities have occurred that could have potentially contaminated the locations or wider environment with HBCD.

The aim is to obtain following numerical data for the inventory:

- Quantity of HBCD produced and used in the past;
- Quantity of HBCD produced and used currently in manufactured products and articles, including production of EPS and XPS for use in buildings (exempted use) and possibly in other uses (e.g. packaging, textile, HIPS for electronics);
- Quantities of HBCD present in articles and products such as in EPS and XPS in use in building and construction sector and possibly in packaging and other uses (e.g. furniture, ornaments, logos);
- Quantities of HBCD in use in flame-retardant textiles (e.g. upholstery in buildings and vehicles);
- Quantities of HBCD in use in other applications (minor uses such as HIPS and adhesives), where relevant;
- Quantities of HBCD in stockpiles and wastes.

Possible applications of HBCD (Table 1) in the country and relevant sites can also be identified for closer studies and site visits, including:

- Current and former production sites of HBCD;

- Manufacturing sites of HBCD containing products and articles;
- Waste collection centres and recyclers;
- Waste management facilities;
- End-of-life vehicles treatment facilities;

2.4.3 Tier III: In-depth inventory

The in-depth inventory may include sampling and analysis of HBCD. Laboratory analysis, although time consuming and expensive, may be necessary in identifying materials containing HBCD. However, in cases where the material dates before 2014 the presence of bromine, confirmed using X-ray fluorescence (XRF) screening, can be a sufficient confirmation on the presence of HBCD in the material on site. Tier III may also involve detailed inspections of sites mentioned in tier II above and in the inventory chapters below.

Appendix 3 contains more information on use of analytics in the inventory process. The screening and analysis of POPs and HBCD containing articles and products is described in the *Guidance on Sampling, Screening and Analysis of Persistent Organic Pollutants in Products and Articles (*UNEP, 2017d). Also Technical guidelines on the environmentally sound management of wastes consisting of, containing or contaminated with hexabromocyclododecane (UNEP/CHW.12/5/Add.7/Rev.1) (UNEP, 2015a) provide information on analytical methods.

Some examples of such studies can be found in published literature: An initial screening of HBCD has e.g. been performed in Japan for curtains[5] (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) detecting HBCD at different levels[6]. A study on HBCD in EPS and XPS waste was carried out recently in the Netherlands (Giraf Results, 2016).

The in-depth inventory may also establish a material and substance flow analysis to understand the stocks and flows of HBCD in different material streams. With a dynamic substance and material flow analysis and the information on the current use/stock of the respective products and the service life of the products, the products entering the waste stream can be estimated and calculated. Such dynamic substance flow analysis has been conducted for HBCD (Li et al., 2016) or PBDEs (Morf et al., 2008; Abbasi et al., 2015). Also see the approach in European Commission (2011) and Potrykus et al. (2019).

2.5 Step 4: Managing and evaluating the data

For general description of Step 4, please refer to Chapter 2.5 of General guidance on POPs inventory development (UNEP/POPS/COP.9/INF/19/Add.1) (UNEP, 2019).

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

2.6 Step 5: Preparing the inventory report

The final stage of the inventory is preparation of the inventory report. This report includes results of inventories of all key sectors investigated by the country compiled in a single document.

The essential elements of the report are:

(a) Objectives and scope;

(b) Description of data methodologies used and how data were gathered, including all the assumptions and conversion factors adopted as a result of expert judgment;

(c) Final results of the inventory for each sector considered a priority for the country (using a format to be provided in the General inventory guidance as such or adapted from that format);

(d) Results of the gap analysis and limitations identified for completion of the inventory;

[5] The life span of quality curtains is more than 20 years (Wrey's, 1997). Therefore HBCD in curtains treated the last decades are to a considerable share still in use.

[6] The levels were partly below HBCD levels used for flame retarding PS (Rani et al., 2014; Hong et al., 2013) indicating that some of the PS were from recycling.

(e) 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 preferences.

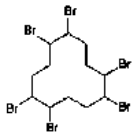
3 Background information on HBCD

3.1 Identity and production of HBCD

HBCD means hexabromocyclododecane (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). It is used as a flame retardant additive to delay polymer ignition and thereby slow the rate at which buildings, articles, vehicles and stored materials catch fire.

HBCD is a cyclo-aliphatic brominated hydrocarbon produced through the bromination of cyclododecatriene. The structural formula of HBCD is a cyclic ring structure with Br-atoms attached. The molecular formula of the compound is $C_{12}H_{18}Br_6$ and its molecular weight is 641 g/mol. 1,2,5,6,9,10-HBCD has six stereogenic centers and, in theory, 16 stereoisomers could be formed (Heeb et al., 2005). However, in commercial HBCD, only three of the stereoisomers are commonly found, namely, alpha (α-), beta (β-), and gamma (γ-) HBCD. Depending on the manufacturer and the production method used, technical HBCD consists of 70-95 per cent γ-HBCD and 3-30 per cent α- and β-HBCD. Information about HBCD characteristics are shown in Table 2.

Table 2: Basic information of HBCD (European Commission, 2008, ECHA, 2009, UNEP/POPS/POPRC.6/13/Add.2, 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)

HBCD has been on the world market since the late 1960s and may still be produced for use in EPS and XPS in buildings, possible under the specific exemption in the Stockholm Convention Annex A. It has been historically produced mainly in China, the European Union (EU), and the United States of America. The total production of HBCD was estimated at around 31,000 tonnes in 2011, of which about 13,000 tonnes were produced in the EU countries and in the United States, and 18,000 tonnes in China (UNEP/POPS/POPRC.7/19/Add.1 (UNEP, 2010a), UNEP/POPS/POPRC.8/16/Add.3 (UNEP, 2011). For comparison, in 2001 demand for HBCD was 9,500-16,500 tonnes

in Europe, 3,900 tonnes in Asia and 2,800 tonnes in North and South America (additional data are available in UNEP/POPS/POPRC.7/19/Add.1 (UNEP, 2011) and UNEP/POPS/POPRC.8/16/Add.3 (UNEP, 2012)). Because of the alternatives having become available since 2014, HBCD is currently likely produced only in China.

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).

Countries where HBCD production takes or took place in the past, should compile data on current (and historic) production, import, export, available information on uses, and possible current stockpiles for the inventory. Also information on the amount of production waste and the historic management and deposition of waste from production could be addressed in the inventory (including associated landfills). These may be relevant for identification of contaminated sites according to Article 6 of the Stockholm Convention as contamination has been detected around HBCD production sites (Li et al., 2012; Morris et al. 2004, Rüdel et al., 2012) (see chapter 3.6 on contaminated sites).

3.2. Uses of HBCD

HBCD has been used as a flame retardant additive to reduce ignition of mainly flammable polymers and textiles in buildings, vehicles or electrical and electronic equipment (EEE). The main uses of HBCD globally are manufacture of expanded and extruded polystyrene foam insulation, while the use in textile applications and electric and electronic appliances is smaller (UNEP/POPS/POPRC.6/13/Add.2) (UNEP, 2010a). It has been estimated that over 90 per cent of HBCD is used as a flame retardant in EPS and XPS foams that are used as insulation materials in industrial and residential buildings in the construction sector (UNEP/POPS/POPRC.7/19/Add.1) (UNEP, 2011). In the EU the main use has been in EPS and XPS, and the uses in HIPS and in textiles are each estimated at 2% (ECHA, 2009). In Japan 80% of the consumption of HBCD was in insulation boards (and tatami mat) and 20% in textiles (Managaki et al., 2009).

The concentrations at which HBCD is used depend on the polymer it is used with as well as the fire safety requirements the product needs to meet (UNEP/POPS/POPRC.7/19/Add.1) (UNEP, 2011). Therefore, there are regional differences in the amounts HBCD is applied. Typical concentrations of HBCD in different materials are shown in table 3 below.

Table 3: Typical concentrations of HBCD in different materials.

Flame-retardant materials	HBCD content (in mg/kg)
Expanded polystyrene (EPS)	5,000-10,000[7]
Extruded polystyrene (XPS)	8,000-25,000[8]
Textile back-coatings Textiles	60,000-150,000[9] 22,000-43,000[10]
High-impact polystyrene (HIPS)	10,000-70,000[11]

Most of HBCD has been used in the European Union, but its use in China has increased over the past decade (UNEP/POPS/POPRC.6/13/Add.2) (UNEP, 2010a); (UNEP/POPS/POPRC.7/19/Add.1) (UNEP, 2011), (UNEP/POPS/POPRC.8/16/Add.3) (UNEP, 2012).

3.2.1 HBCD use in flame retardant EPS and XPS

There are a number of uses for flame retardant EPS and XPS in construction sector, packaging and other applications, from insulation to furniture and decoration. Alternatives to HBCD have not become available for most

[7] Submissions by Canada and PlasticsEurope/Exiba to the Stockholm Convention, 2011 (UNEP/POPS/POPRC.7/19/Add.1) (UNEP, 2011).

[8] BFRIP 2005, XPSA and CPIA, PlasticsEurope/Exiba submissions to the Stockholm Convention, 2011 (UNEP/POPS/POPRC.7/19/Add.1) (UNEP, 2011).

[9] European Commission, 2008; Environment Canada and Health Canada, 2011 (UNEP/POPS/POPRC.7/19/Add.1) (UNEP, 2011)

[10] Kajiwara et al., 2009.

[11] ECHA, 2009 (UNEP/POPS/POPRC.7/19/Add.1) (UNEP, 2011).

common production process for EPS raw material until in 2014. Therefore it can be assumed in most regions that flame retardant EPS and XPS produced before 2014 contains HBCD.

Continued use of HBCD has been possible after the listing under certain conditions (Annex A, Part VII of the Stockholm Convention; see Chapter 1.1). In case the use of HBCD has continued for insulation in buildings in the country (after ratification and registration for exemption under Article 4), the EPS and XPS containing HBCD should be easily identifiable by labelling or other means and separated from other EPS and XPS.

Construction sector

There is a variety of different uses for EPS and XPS materials in the construction sector (see Table 5, Rani et al., 2014). In addition to insulation, also other molded EPS decorative elements can be found in buildings.

The use of flame-retardant EPS and XPS insulation varies significantly between countries, depending on local building codes and fire safety regulations (Blomqvist et al., 2010). The wider use in insulation boards started in the 1980s (European Commission, 2008). In some countries, virtually all EPS and XPS are flame retardant, while in some countries flame-retardant-free EPS and XPS can be used for many applications. Due to their high volumes and bulky sizes and the costs associated with transporting them, polystyrene foam insulation products are usually manufactured mainly for local consumption rather than export (Posner et al, 2010; BSEF, 2011). The raw material, however, is commonly traded between countries and transported long distances.

The service life of buildings and their polystyrene foam components can be 25-100 years, and information on the historical use of HBCD containing materials is of importance for planning and ensuring environmentally sound management. Since the alternative flame retardants in XPS/EPS have only become available gradually in 2014, all flame retardant polystyrene foam until 2014 can be assumed to contain HBCD. All of the EPS and XPS used in buildings and construction are likely to not contain HBCD (in case materials without flame retardant can be used in the country), which needs to be accounted for in the calculations based on total volumes of EPS/XPS used for these purposes.

Insulation boards with HBCD may also be found in road and railway embankments (UNEP/POPS/POPRC.6/13/Add.2) (UNEP, 2010a), mines and tunnels.

In the manufacture HBCD is applied in flame-retardant EPS at 0.5 - 1.0 % by weight and in flame-retardant XPS at 0.8 – 2.5 % in XPS by weight (Table 3). These concentrations can be applied when calculating the amount of HBCD in the used polystyrene foam in the country. For an inventory also the total volume of EPS and XPS containing HBCD in current use should be estimated since these are the materials which eventually need to be managed as waste.

Other EPS and XPS uses

Outside the construction sector, polystyrene (PS) foams have been also used to insulate coolers, as a packaging material, decorations and ornaments, although the materials in these applications may also be without flame retardant. HBCD has been used in EPS filling in nursing pillows and bean bags used as easy chairs (UNEP/POPS/POPRC.6/13/Add.2) (UNEP, 2010a). The use of flame retardant grade EPS for these applications depend on local requirements, as well as the quality of EPS raw material that may be available (logistical reasons). In the EU, HBCD is not used in food packaging (ECHA, 2009), but flame-retardant EPS has been found in other packaging materials (EUMEPS, 2009). In a South Korean survey of PS food contact materials HBCD was also discovered in ice box and in fish tray (Rani et al. 2014).

EPS and XPS in packaging

Use of flame-retardant grade polystyrene foam in packaging varies between countries and regions. In Europe Applications of polystyrene foam in packaging generally would not require the use of HBCD or other flame retardants (European Commission, 2008). However, even applications where flame-retardancy is not specifically required may still contain flame-retardant, e.g. when flame-retardant EPS raw material is more readily available (UNEP/CHW.12/5/Add.7/Rev.1) (UNEP 2015a).

The service life of packaging material is much shorter that construction materials, and the situation varies from country to country and over time. Much of the old packaging material has already been disposed of. Also possible recycling has an impact. Screening of XPS and EPS in South Korea revealed the use and/or recycling of HBCD containing EPS in packaging (Rani et al., 2014). However, in the study made in the Netherland in 2018, relevant concentrations of HBCD were only found in packaging waste and construction waste, and new packaging material did not contain HBCD (Potrykus et al., 2019).

In the inventory it needs to be addressed whether the packaging materials contain HBCD for any reason (e.g. because the EPS raw material in the region contains HBCD, packaging material is imported, or HBCD from recycled EPS waste has contaminated new products).

XPS and EPS in furniture and nursing pillows

XPS and EPS containing HBCD have also been used in furniture and nursing pillows (UNEP/POPS/POPRC.6/13/Add.2) (UNEP, 2010a). Also loose-filled furniture, such as bean bags, may contain flame-retardant EPS. The extent of flame-retardant EPS and XPS use in furniture (e.g. child seat) is not clear and there are likely regional differences. Such information should be collected by detailed interviews of the manufacturers and importers, and if necessary screening in the later stages of the inventory.

Vehicles

Insulation boards with HBCD may also be found in vehicles (UNEP/POPS/POPRC.6/13/Add.2) (UNEP, 2010a), such as cold storage trucks. HBCD can also be found in other materials in other vehicles, such as in upholstery, seat belts and thermal covers.

Other moulded EPS articles, such as ornaments, decorations, logos, etc.

EPS is used for ornaments and decorations. If manufacture takes place, the regulations require use of flame-retardant grade for such products and such products are on the market, they should also be considered in the inventory.

Considering the information above, the inventory of HBCD in EPS and XPS should address the following:

- HBCD in current EPS and XPS production for building & construction, transport, packaging and furniture;
- Import of HBCD containing polystyrene foams in building & construction, transport, packaging and furniture sectors;
- HBCD containing EPS and XPS in use and stock in building and construction;
- HBCD containing EPS and XPS in use and stock in packaging[12], furniture and other uses;
- HBCD in EPS and XPS in recycling and end-of-life.

3.2.2 HBCD in textile back-coatings, furniture and transportation upholstery and clothing

The second largest application of HBCD globally was as flame-retardant in polymer dispersion on cotton or cotton mixed with synthetic blends in the back-coating of textiles (Table 5; UNEP/POPS/POPRC.6/13/Add.2, UNEP 2010a). HBCD might still be used in textiles in countries having not ratified the Stockholm Convention or the HBCD amendment. For countries that have ratified the HBCD amendment to the Stockholm Convention, this use is prohibited, but the textiles may still be in use.

Textiles can be treated with flame retardants through fabric impregnation or spraying or by spinning flame-retardant polymers into textile yarns. Back-coating to textiles has been applied by adding a dispersion containing a polymer and HBCD among other additives as a thin coating film (ECHA, 2009). The application of flame retardants in textiles depends on the flammability standards in the country (Horrocks, 2013; Shaw et al., 2010). HBCD containing textiles were mainly used in upholstery fabrics (UNEP/POPS/POPRC.6/13/Add.2) (UNEP, 2010a). Depending on the fire-safety regulations including building code, textiles in residential homes, public buildings (including hospitals and prisons), airports or hotels may be flame retarded (UNEP/POPS/POPRC.6/13/Add.2; UNEP, 2010a; Horrocks, 2013).

Flammability standards define material specific ignitability requirements for different materials, and meeting those standards may require use of flame retardants. 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 are different in different countries or regions (Horrocks, 2013; Shaw et al., 2010). The requirements of the respective standards form a basis for understanding the scope of HBCD use in the application, and should be studied closely in the inventory.

Textile applications for HBCD include (European Commission, 2008; UNEP/POPS/POPRC.6/13/Add.2 (UNEP, 2010a); UNEP/CHW.12/5/Add.7/Rev.1 (UNEP, 2015a)):

- Residential and commercial upholstered furniture;

[12] EPS packaging is not usually made of flame-retardant EPS unless specifically required or when the only available EPS raw materials are flame-retardant.

- 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 (e.g. fire-fighters and military);
- Tents;
- Other treated textiles.

The concentrations of HBCD used in the production of flame-retardant textiles are much higher than those used in polystyrene foam production (Table 3). HBCD can be present in flame retardant textiles at concentrations ranging from 2.2 % – 4.3 % (Kajiwara et al., 2009) or even up to 15 % (UNEP/POPS/POPRC.6/13/Add.2) (UNEP, 2010a). While the total use volume of HBCD in textiles was considerably lower than for EPS and XPS, the environmental releases of these two applications were similar in Europe (ECHA, 2009).

In consultation with the individual stakeholders, the current and former use of HBCD for the textile sectors should be clarified for estimation of the total volume of HBCD currently and historically used in the sector. Also the amount of materials treated with HBCD should be estimated.

The different textile applications treated during the last approximately 40 years have partly likely been disposed of 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 nevertheless be still in use.

HBCD in Transport textiles

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 that are used 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[13].

It is unclear which textiles used in the transport sector may contain HBCD. Many flame-retardants have been used for different fabrics, including HBCD and PBDEs. In a study in Japan HBCD was detected in 50% of the analysed floor coverings (n=4) but not in any of the analysed seat fabrics (n=16) (PBDEs were detected in textiles)[14] (Kajiwara et al., 2014). HBCD was also detected in door trim fabrics in this study.

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 screening study high levels of flame retardants (including HBCD) were detected in dust in commercial airplanes (Allen et al., 2013).

In railways flammability standards which set requirements for the fire safety of the materials used may exist on national or regional level (e.g. European Directive 2008/57/EC) (Horrocks, 2013). Therefore also for this sector use of HBCD may have been used in relevant volumes. However, there are no studies on HBCD in trains.

HBCD use in textile applications used indoors

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

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

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

coverings and draperies (UNEP/POPS/POPRC.6/13/Add.2 (UNEP, 2010a); Horrocks, 2013). It has been concluded that indoor contamination with HBCD is a relevant exposure pathway to humans (Harrad et al., 2010b)[15].

Also for furniture application the national flammability standards (e.g. in the United States and the UK) may require the use of flame retardants, as documented for POP-PBDEs (UNEP, 2015c; Shaw et al., 2010, Stapleton et al. 2012; Chicago Tribune, 2012). Such national flammability standards most probably also trigger the use of HBCD or other flame retardants in such applications and would be assessed within the inventory.

Only a few studies on HBCD in home textiles have been performed. A 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 %.

HBCD use in clothing

HBCD was also used 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. The extent of use of HBCD is not known.

Also for nightwear and other clothing flammability standards exist in some countries (e.g. British Standards (BS) 54 Update on Flame Retardant Textiles 5722) which have resulted in the use of flame retardants even in children sleepwear (Blum & Ames, 1977). Flammability standards do not necessarily require the use of any flame retardant, if the fibre used is inherently inflammable (Adivarekar & Dasarwar, 2010) (Table 4).

Table 4: 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 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, 02/2007.
Australia and New Zealand	Australian Government (2007): 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). (Standards Association of Australia, 2003).

Industries manufacturing or importing personal protective textiles (e.g. for fire fighter and military uniform; other professional technical textiles), retailers and institutions using these textiles (fire fighters or military) should be contacted by direct interviews or by questionnaires for the inventory, if considered relevant in the country.

Considering the information above, inventory of HBCD in textiles should address the following:

- HBCD in textiles used in transport sector;
- HBCD in textile used indoor;
- HBCD in textile clothing;
- Related end-of-life management.

[15] 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.

3.2.3 HBCD in adhesives, paints and HIPS

Minor uses of HBCD include its use as a flame-retardant additive in adhesives and paints and high-impact polystyrene (HIPS) for electrical and electronic equipment. 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).

HBCD has been used in production of HIPS for casings of electrical and electronic equipment (EEE) (UNEP/POPS/POPRC.6/13/Add.2) (UNEP, 2010a), and the casings or parts of electronics as well as plastic fractions from recycling of waste electrical and electronic equipment (WEEE) might contain HBCD. Although HBCD has been largely replaced in HIPS, it has been commonly present in the past. In a study in Switzerland, approximately 18% of IT equipment and 3% of TV housings made from HIPS contained HBCD (Wolf, 2001; Waeger et al., 2010). However, in a more recent screening of BFRs in mixed WEEE plastic from shredders in several European countries, HBCD was below the detection limit 200 mg/kg plastic (Waeger et al., 2010; Waeger et al., 2012). According to Potrykus et al. (2019) HBCD may occur in recycled plastics and products made thereof (including toys) in concentrations ranging from a few mg/kg up to more than 1000 mg/kg. Different equipment with different quality is produced for different regions, and the situation may vary.

HBCD has been largely replaced with other flame retardants in these applications (UNEP/CHW.12/5/Add.7/Rev.1) (UNEP, 2015a) and they could be justifiably given a lower priority in the inventory activities.

Table 5 below compiles the information on different uses of HBCD as well as its production, and the related waste release media.

Table 5: Overview of the production and application of HBCD and their release media into the environment (Based on UNEP/POPS/POPRC.6/13/Add.2 (UNEP, 2010a), UNEP/POPS/POPRC.7/19/Add.1 (UNEP, 2011) and UNEP/CHW.12/5/Add.7/Rev.1 (UNEP, 2015a)).

Group	Source materials /Substance used	Applications /Processes	End Product	Release Media
HBCD CHEMICAL PRODUCTION				
Chemical Production	Cyclododecatriene, bromine	Chemical synthesis	HBCD chemical	• Solid waste • Water • Sludge • Air
HBCD MIXTURE PRODUCTION (Emptied packages of HBCD chemical have been identified as an important source of emissions among first-line users of HBCD and appropriate waste management has reduced emissions significantly				
CD mixture production	Styrene, pentane, HBCD and other additives	Production of flame retardant EPS raw materials	PS beads containing a blowing agent for EPS production	• Solid waste • Landfill leachate • Wastewater cleaning • Sludge • Air
	PS, HBCD and other additives	Production of flame retardant XPS HBCD masterbatches	HBCD masterbatch compound for XPS production	
	Surfactants, HBCD, antimony tri-oxide, acrylic adhesive	Production of flame retardant textile backcoatings	Textile back-coating mixture	
	Textiles, HBCD	Production of impregnated textiles	Flame-retardant textiles	
	Polymer, HBCD	Production of flame retardant yarn	Flame-retardant polymer for spinning into textile yarn	
	HIPS pellets, HBCD antimony trioxide,	HIPS	Flame-retardant HIPS pellets	
		Styrene-acrylonitrile plastics	Styrene-acrylonitrile resins	
			HBCD packaging	
		Production of adhesives and paints	Adhesives, paints	
			HBCD packaging	

PRODUCTION OF ARTICLES CONTAINING HBCD (The boxes below include articles that have become wastes. Such wastes may also be generated at production sites, such as leftovers, cutting waste, etc.)					
XPS articles	XPS masterbatches or PS, HBCD and other additives (including blowing agents such as CO_2)	Expansion and Extrusion	Flame-retardant XPS insulation boards: - Cold bridge insulation - Floors - Basement walls and foundations Inverted roofs - Ceilings - Cavity insulation Composite panels and laminates	• Solid waste • Landfill leachate • Liquid industrial and household cleaning waste • Wastewater • Sludge • Air	
EPS articles	EPS beads	Expansion and molding	Flame-retardant EPS insulation, including insulation boards: - Flat roof insulation; pitched roof insulation; floor insulation 'slab-onground' 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	• Solid waste • Landfill leachate • Liquid industrial and household cleaning waste • Wastewater • Sludge • Air	
			EPS concrete bricks, EPS concrete		
			Soil stability foam (for civil engineering use)		
			Seismic insulation		
			Packaging materials made of PS foams (normally not flame)[16]		

[16] EPS packaging is not usually made of flame-retardant EPS unless specifically required or when the only available EPS raw materials are flame-retardant (i.e. EPS raw material fractions that are not suitable for insulation boards can be used in the packaging material production).

			Other molded EPS articles, such as ornaments, decorations, logos, etc.	
Textiles	Flame-retardant textiles (backcoating or fabrics)		Residential and commercial upholstered furniture	• Solid waste • Landfill leachate • Liquid industrial and household cleaning waste • Wastewater • Sludge • Air
			Transportation seating	
			Wall coverings and draperies	
			Protective clothing and other technical textiles	
			Tents etc.	
Electric and electronic equipment	HIPS pellets	Production of casings for electronic and electric equipment	Electric and electronic appliances	• Solid waste • Landfill leachate • Liquid industrial and household cleaning waste • Wastewater • Sludge • Air

3.3 Import and Export of HBCD as a chemical or in products

Information on imports of HBCD could be available from custom services, or HBCD using industries (especially EPS raw material producers) and related industry associations. Information on import and export of articles containing HBCD should be sought from industries manufacturing them (in particular industries producing polystyrene insulation foam and packaging; textiles and EEE plastic materials). Information on both current and historic imports and exports should be sought. When contacting the relevant stakeholders for the information on the import of HBCD as a chemical, also information on the related uses should be sought.

The HS codes used by the customs are normally not specific enough to address a specific chemical or chemical in products/articles in import or export (Korucu et al., 2014). Therefore HS codes can currently not be utilized for assessing imports/exports of either HBCD or HBCD containing products and articles. CAS numbers and trade names should be used (see Table 1).

The information on imports and exports of HBCD should be compiled in the inventory report. The information should be cross-checked by comparing it with any available information on the material flows in main uses described in 3.2.

3.4 HBCD recycling

Recycling polystyrene products and articles into new products takes place and may involve pre-treatment processes such as compaction.

A study of XPS and EPS in South Korea found HBCD containing PS in packaging (Rani et al., 2008) and buoy (Hong et al., 2013)[17], likely originating from recycling. The overall relevance of HBCD in WEEE plastic is considered to be low and no specific inventory activity is recommended, unless there is evidence of on-going or recent use in HIPS. HBCD can still be present in old electronic equipment. While presence of HBCD cannot be ruled out, assessing the HBCD in recycled streams for the inventory would require chemical analyses and is likely not worthwhile due to use of alternative flame retardants, unless there is specific evidence on significance.

Stockholm Convention prohibits recycling of HBCD. All HBCD containing materials may, however, have been recycled into new products prior to listing in the Stockholm Convention. In addition, recycling may take place when HBCD-containing materials are not identified and removed from the recycling stream. Further contamination of

[17] Buoy made from PS are abundantly used in aquaculture farms and along the coasts and could be a source of HBCD in the marine environment.

recycled materials may also take place in countries which are not Parties to the Convention. A survey on the occurrence of brominated flame retardants in black thermo cups and selected kitchen utensils purchased on the European market detected no HBCD[18] (Samsonek & Puype, 2013) and indicated that the overall level of HBCD in flame retarded waste plastic recycled into (such) products was low. However, according to Potrykus et al. (2019), HBCD occurs in recycled plastics and products made thereof (including toys) in concentrations ranging from a few mg/kg up to more than 1000 mg/kg, due to past and current recycling activities.

An assessment on whether HBCD is likely present in recycling streams (e.g. if EPS/XPS insulation foam from construction is recycled or if e.g. EPS/XPS from packaging is recycled) could be carried out in the context of the consultations with the industry. This would also contribute to the considerations on how to ensure environmentally sound management of the waste containing HBCD at the end of life.

3.5 HBCD in waste

Due to the long service-life of products where HBCD has primarily been used, waste management represents a potentially increasing source of HBCD releases to the environment (Figure 1). Basel Convention has developed a set of technical guidelines to assist Parties on the environmentally sound management (ESM) of waste consisting of, containing or contaminated with persistent organic pollutants. The main document is *Draft updated general technical guidelines on the environmentally sound management of wastes consisting of, containing or contaminated with persistent organic pollutants* (UNEP/CHW/COP.14/7/Add.1; UNEP, 2018), which should be used in conjunction with the substance specific technical guideline. For wastes consisting of, containing or contaminated with HBCD, the "*Technical guidelines on the environmentally sound management of wastes consisting of, containing or contaminated with Hexabromocyclododecane*" has been prepared (UNEP/CHW.12/5/Add.7/Rev.1; UNEP, 2015a).

The technical guidelines provide a framework for management of POPs waste by defining elements that are relevant for managing the waste in an environmentally sound manner, e.g. provisional concentration limits for what is considered low persistent organic pollutant content (Article 6 of the Stockholm Convention) and the methods that constitute environmentally sound disposal.

Volumes of waste containing HBCD should be addressed in the inventory. These could include the amount of EPS/XPS, textile and WEEE waste managed by recycling companies, estimation of future amounts from demolition and refurbishing buildings as well as waste from new construction. Examples on how the formation of HBCD waste over time can be estimated can be found in Morf et al. (2008), European Commission (2011), and Potrykus et al. (2019).

[18] The BFR detected were decabromodiphenyl ether (decaBDE) listed in the Convention in 2017, as well as other BFRs such as tetrabromobisphenol A (TBBPA), tetrabromobisphenol A bis(2,3-dibromopropyl), ether (TBBPA-BDBPE) and decabromodiphenylethane (DBDPE).

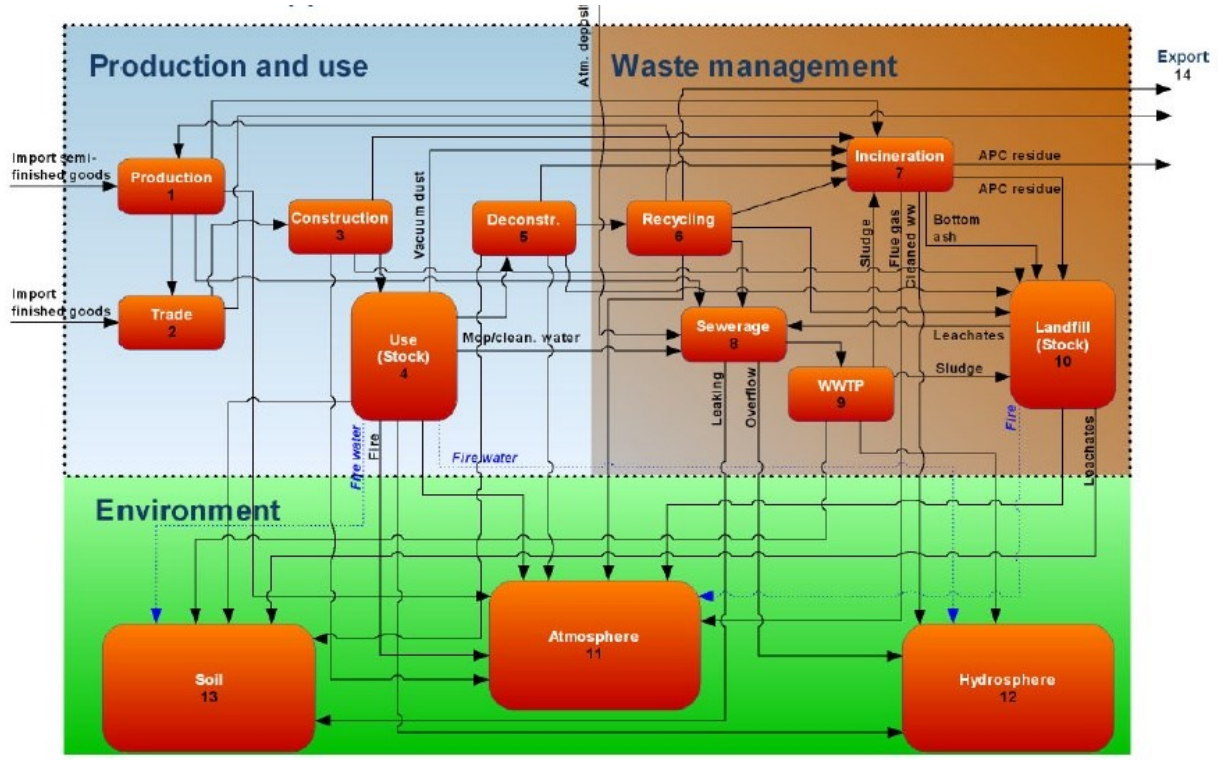


Figure 1: Material and substance flow of HBCD in construction and impacted materials in production/use and waste management and related releases to the environment (Morf et al., 2008)

3.6 HBCD contaminated sites

Stockholm Convention Article 6 requires Parties to endeavour to develop appropriate strategies for identifying sites contaminated with POPs. Collecting information on HBCD-contaminated sites in the context of an inventory may be useful for such a strategy. For the identification of HBCD-contaminated sites the inventory team should consider the step-by-step approach in UNIDO's *Persistent Organic Pollutants: Contaminated Site Investigation and Management Toolkit* (UNIDO, 2010), which contains the identification of POP-contaminated sites (although not specifically covering HBCD sites), assessing related risks and setting priorities.

All sites where production of HBCD, the manufacture of products and articles containing HBCD, the use of these products, recycling and the end-of-life treatment of these products has taken place may be potentially contaminated (Table 6). For some HBCD production sites and also downstream use of HBCD 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). Specifically the management of HBCD packaging material (disposed of by users of HBCD, e.g. manufacturers of EPS raw material) has been identified as a source of contamination (UNEP, 2010a). It should also be noted that HBCD is not essentially released from insulation boards during use (UNEP, 2010a), and significant contamination from presence of undisturbed EPS and XPS insulation boards should not be expected.

A site is generally considered contaminated by a POP when the concentration of one or more contaminants exceeds the regulatory criteria or poses a risk to humans and/or the environment. There are currently no established regulatory limits for HBCD in soil. Contamination can be estimated by comparing the levels with background levels, which are below 1 ng/g in all regions (Harrad et al. 2010a, Desborough 2011, Tang et al. 2014). Levels in soil in contaminated areas are several orders of magnitude higher e.g. at a formulator/compounder plant in the UK (18,700 – 89,600 ng/g; Dames and Moore, 2000) or at a XPS production facility in Sweden (140 – 1300 ng/g; Remberger et al. 2004). Levels measured in London were up to 420 ng/g with increasing levels in soil close to buildings (Harrad et al., 2010a; Desborough, 2011).

Environmental contamination from releases from processes and deposits can affect air, water/sediments and land as well as biota including food (Dames and Moore, 2000; Morris et al., 2004; Li et al. ,2012, Remberger et al. 2004; Rüdel et al., 2012; Eljarrat et al. 2005; Eljarrat et al., 2011).

Table 6: Potential HBCD-contaminated sites

Life 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 HBCD were used in EPS and XPS production and in textile and related industries	EPS/XPS industry currently or 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 Factories micronising HBCD	Site of production; Landfill site of related wastes; Impacted surface waters (sediment and flood plains)
Use of articles and products containing HBCD	Sites where textiles containing HBCD is used	Soil impacted from buildings/city[19]
	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- wastes
	Open burning or non-BAT incineration of HBCD-containing waste[20]	Related sites and sites were residues/ashes are disposed
	Application sites of HBCD impacted sludge	Agriculture land

The following literature could be consulted when considering HBCD contamination:

- Contamination at/around HBCD production sites (Allchin & Morris 2003 ; Morris et al. 2004; Li et al. 2012, Rüdel et al. 2012);
- Contamination from HBCD using industries (plastics, 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);
- Recycling of HBCD containing wastes (Gao et al., 2011; Tomko & McDonald, 2013);
- Landfills and dump sites (Remberger et al., 2004; Weber et al., 2011);
- Application of highly contaminated industrial sludge from (industrial) waste water treatment[21] (not documented for HBCD).

[19] The comparison of HBCD in soils in UK cities compared to rural environment revealed higher levels in cities with elevated concentration in some city soils (Harrad et al. 2010a). For one house a transec study found decreasing HBCD levels in soils with increasing distance from the house which were below 1 mg/kg (0.29 mg/kg at 3 m; 0.12 mg/kg at 5 m, 0.035 mg/kg at 7 m and 0.015 mg/kg at 12 m distance, Desborough 2011).

[20] 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).

The quantities in the landfills may be high due to past waste management practices. For example, it has been estimated in the EU that almost 30% of EPS/XPS panels containing HBCD have been landfilled (Potrykus et al., 2019).Brominated flame retardants including HBCD and POP-PBDEs can be released from these materials by landfill leachate or accidental fires (Danon-Schaffer et al. 2014; Gullett et al. 2009; Odusanya et al. 2009; Weber et al. 2011, Remberger et al. 2004).

[21] The contamination pathway via sewage sludge has been documented for other POPs production (Washington et al. 2010; Oliaei et al. 2013)

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Appendix 1. Questionnaire on use of HBCD in EPS and XPS

Sample questionnaire for requesting information on the presence of HBCD in Expanded Polystyrene (EPS) and Extruded Polystyrene (XPS) in insulation in construction, packaging, and other uses and related recycling and waste

Background information

In May 2013, hexabromocyclododecane (HBCD) was listed in the Stockholm Convention as a persistent organic pollutant (POP) in Annex A, with a view to eliminating it completely. [Describe when your country ratified and how it has been restricted, including if it has registered for the exemption.]

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 domestic 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.

Manufacture of flame-retardant Expanded Polystyrene (EPS) and Extruded Polystyrene (XPS) for the construction sector have been 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, as both EPS and XPS are available also in non-flame retardant varieties. Recently also alternative flame retardants have become available for EPS/XPS. EPS/XPS packaging is normally flame-retardant and does not contain HBCD. However, it cannot be excluded that packaging materials would contain HBCD.

Purpose 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 applications.

This information will constitute the basis for a country to manage HBCD and related treated materials as part of the update of the National Implementation Plan of the country.

1. Name and address of industry:

Name of industry/company or institution	Address

2. Type of company or industry:

☐ Production of EPS raw material

☐ Import/export of EPS raw material

☐ Manufacture of EPS or XPS foams for building & construction

☐ Manufacture of EPS or XPS foams for packaging

☐ Manufacture of EPS or XPS for other purposes, please specify _____

☐ Import of EPS and XPS for building & construction, packaging or other purpose

☐ Retail of EPS and XPS foam for building & construction

☐ Retail of EPS XPS for packaging production

☐ Recycling of EPS or XPS

☐ Disposal of EPS or XPS

☐ Other industry related to EPS/XPS, please specify _____

3. Estimated amount of HBCD used in EPS and XPS for manufacture of different products and use (please fill in the information in tables 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?

_____

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 EPS containing HBCD (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 moulded EPS articles, such as ornaments, decorations, logos, etc.			……t/……t
Other EPS application (please specify):			……t/……t ……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 XPS containing HBCD (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. Recycling of EPS and XPS and related HBCD containing products and waste

Although EPS and XPS as materials can be recycled, the recycling of EPS and XPS that contains HBCD is not allowed in the Convention. The provisional limits set by Basel Convention for recycling are 100 or 1000 mg/kg (specify national regulations). In the following table available information or estimates on EPS/XPS recycled, the related HBCD content and the final products are requested to be listed.

EPS/XPS materials used in recycling (tonnes)	HBCD content (mg/kg)*	Products made from recycling (tonnes) Related HBCD content (mg/kg)*	Waste generated during recycling (tonnes) Related HBCD content (mg/kg)*

* Please provide the levels/range of HBCD in case it is discovered in recycling and provide as detailed information as possible

5. Information on waste containing HBCD (from production and end of life) and related management[22]

Type of waste/stockpile	**- total volume (tonnes)** **- HBCD content (%)** **- address/location** **- condition of stockpile**	**Waste management (please specify how the waste is expected to be disposed of)**
(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.)		
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);		

[22] For the environmental sound management of HBCD containing waste see the Draft Technical guidelines on the environmentally sound management of wastes consisting of, containing or contaminated with hexabromocyclododecnae (UNEP 2015).

6. Locations contaminated or possibly contaminated with HBCD or EPS/XPS containing HBCD (Please see chapter 3.6 of the HBCD inventory guidance)

Location/address	**Type of contamination (impacted river or land or landfill) and extent ***	**Type of activity at the location**	**Has the site been investigated?**	**Levels of HBCD in soils and sediments (if available)**

7. Further Remarks

8. Contact information of the person for more information

Name	
Department	
Position	
Telephone	
Mobile Phone	
Email Address	
Signature of respondent	
Date	

Appendix 2. Questionnaire on the use of HBCD in textiles

Sample questionnaire for requesting information on the presence of HBCD in textile applications and related recycling and waste.

Background information

In May 2013, hexabromocyclododecane (HBCD) was listed in the Stockholm Convention as a persistent organic pollutant (POP) in Annex A, with a view to eliminating it completely. [Describe when your country ratified and how it has been restricted, including if it has registered for the exemption.]

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 domestic 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.

An important application of HBCD is in polymer dispersion on cotton or cotton mixed with synthetic blends or synthetic, in the back-coating of textiles (UNEP, 2010a). The HBCD use in textiles has been prohibited in the Stockholm Convention provisions. Therefore the use of HBCD in this application needs to be stopped and the treated textiles are not allowed to be recycled. Related waste must be disposed of as POPs waste (UNEP, 2015a).

Aim of this questionnaire

This questionnaire is aimed at gathering information on the current and former use of hexabromocyclododecane (HBCD) in textiles. These include textiles containing HBCD in the transport sector, flame retarded textiles in indoor use (e.g. curtains, furniture, matress ticking) and flame retarded clothing (e.g. fire fighter uniform; military uniform; sleep wear). Please note that other flame retardants have been available for textile applications and not all textiles contain HBCD.

The information on current and former use of HBCD in the textile sector 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.

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[23]	☐	Manufacturing of textiles applications used indoor[24]	☐
Manufacturing of flame retarded textile clothing[25]	☐	Import of textiles in transport seating and other textile/synthetics in transport sector[23]	☐
Import of flame retarded textile applications used indoor[24]	☐	Import of flame retarded textile clothing[25]	☐
Retail sale of textiles in transport seating and other textile/synthetics for transport sector[23]	☐	Retail sale of flame retarded textiles applications used indoor[24]	☐
Retail sail of flame retarded textile clothing[25]	☐	Recycler of possibly flame textiles from transport sector[23], flame retarded textiles applications used indoor[24], flame retarded textile clothing[25]	☐
Disposal of textiles in transport seating and other textile/synthetics in transport sector[23], textiles applications used indoor[24], textiles clothing[25]	☐	Others (Please specify):	☐

3. Indicate the type of textiles you deal with

Textiles for transport seating and other textile/synthetics in transport sector[23]	☐	Flame retarded textiles applications used indoor[24]	☐
Flame retarded clothing[25]	☐	Textiles for recycling to produce other products	☐
Flame retarded textiles for disposal	☐	Others (Please specify):	☐

[23] Flame retardant textiles in transport may have been used in e.g. upholstery of seating, floorcoverings, roof-lining fabrics and other furnishings within the vehicle or vessel interior.

[24] This may include e.g. curtains, textile upholstery of furniture, bed mattress ticking, wall coverings and draperies ((UNEP/POPS/POPRC.6/13/Add.2) (UNEP, 2010a); Horrocks, 2013).

[25] 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.

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

Was or Is HBCD currently used in your textile production, or textiles used or sold? (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 may find information for the table in safety data sheets or from 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: Estimated past and current use of HBCD in different flame retarded textile application, related content and textile volumes

Manufacture of flame retardant textiles	**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[26] (Please use separate sheet if necessary to document all information)

Type of waste/stockpile	**- total volume (tonnes)** **- HBCD content (%)** **- address/location** **- condition of stockpile**	**Waste management (please specify how the waste is expected to be disposed of)**
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:

[26] For the environmental sound management of HBCD containing waste see the Draft Technical guidelines on the environmentally sound management of wastes consisting of, containing or contaminated with hexabromocyclododecane (UNEP, 2015a)

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	Has 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

8. Contact information of the person for more information

Name	
Department	

Position	
Telephone	
Mobile Phone	
Email Address	
Signature	
Date	

Appendix 3. Analytical considerations in making the inventory

One of the essential elements in an inventory is to be able to distinguish between the materials that contain HBCD from those that do not. As explained in Chapter 3, this information should be sought from literature, manufacturers, importers, users and trade. However, it is likely that all materials where HBCD has been used are found also found non flame retardant, or flame retarded with other flame retardants than HBCD (e.g. textiles, HIPS). In the in-depth inventory, as well as in ensuring environmentally sound waste management according to Article 6 of the convention, some analytical tools may need to be involved.

The typical concentrations at which HBCD is used are presented in Table 1. It can be assumed that the concentration of HBCD in EPS and XPS as well as HIPS remains the same in the course of its service-life, i.e. there are no significant releases from undisturbed materials. Contrary to that, HBCD applied in textiles, upholstery, back-coatings etc. may be released into the environment and consequently the concentrations in the material reduced. Identification of such materials may therefore be more difficult and require higher-end analytical tools.

Presence of HBCD (as well as other brominated flame retardants), can be in some cases confirmed by screening the bromine content of articles with a handheld XRF equipment. Handheld XRF equipment are multi-purpose and widely available, and relatively inexpensive (see e.g. UNEP, 2017c and UNEP, 2017d).

Until 2014 HBCD was the only brominated flame retardant used in the most common EPS production process. Bromine positive XRF tested materials dating before 2014 could therefore be considered to contain HBCD as a conservative estimate. It should be noted in the inventory report that the bromine could also be because of other brominated flame retardants (such as PBDEs) (see e.g. Kajiwara et al. 2014).

Starting in 2014, HBCD has been increasingly replaced by other brominated flame retardants. Useful guidance for the analytics of HBCD in foams has been developed by CEFIC and Plastics Europe (http://chm.pops.int/Portals/0/download.aspx?d=UNEP-POPS-NIP-GUID-SUB-SC7-10-EHBCDIG-1.En.pdf).

For other materials than PS insulation, the XRF tested bromine positive samples should be further analysed for HBCD for confirmation (UNEP, 2017b). The likelihood of the bromine in the material originating from the use of HBCD as a flame retardant decreases all the time as alternatives are being phased out (see *alternatives guidance*).

For more information on sampling and analytics, please consult Guidance on Sampling, Screening and Analysis of Persistent Organic Pollutants in Products and Articles (UNEP/POPS/COP.7/16) (UNEP, 2017d).

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