UN environment

BASEL CONVENTION
TECHNICAL GUIDELINES

Technical guidelines on the environmentally sound management of wastes consisting of, containing or contaminated with hexabromocyclododecane

BASEL CONVENTION

TECHNICAL GUIDELINES

TECHNICAL GUIDELINES ON THE ENVIRONMENTALLY SOUND MANAGEMENT OF WASTES CONSISTING OF, CONTAINING OR CONTAMINATED WITH HEXABROMOCYCLODODECANE

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Contents

Abbreviations and acronyms

BAT	best available techniques
BEP	best environmental practices
CAS	Chemical Abstracts Service
EC	European Commission
EPS	expanded polystyrene
ESM	environmentally sound management
EU	European Union
HBCD	hexabromocyclododecane
HIPS	high-impact polystyrene
IEC	International Electrotechnical Commission
OECD	Organisation for Economic Co-operation and Development
PBDD	polybrominated dibenzo-p-dioxin
PBDEs	polybrominated diphenyl ethers covered by the Stockholm Convention (tetra-, penta-, hexa- and hepta-BDE)
PBDF	polybrominated dibenzofuran
PBT	polybutylene terephthalate
PCB	polychlorinated biphenyl
PCDD	polychlorinated dibenzo-p-dioxin
PCDF	polychlorinated dibenzo-furan
PCT	polychlorinated terphenyl
POP	persistent organic pollutant
PS	polystyrene
PUR	polyurethane
PXDD	polyhalogenated dibenzo-p-dioxin
PXDF	polyhalogenated dibenzofuran
UNEP	United Nations Environment Programme
WEEE	waste electrical and electronic equipment
XSP	extruded polystyrene
XRF	X-ray fluorescence

Units of measurement

mg/kg	milligram(s) per kilogram. Corresponds to parts per million by mass.

I. Introduction

A. Scope

1. The present guidelines provide guidance on the environmentally sound management (ESM) of wastes consisting of, containing or contaminated with hexabromocyclododecane (HBCD), pursuant to several decisions of two multilateral environmental agreements on chemicals and wastes.[1]

2. HBCD was listed in Annex A to the Stockholm Convention in 2013 and the amendment entered into force in 2014.

3. The present guidelines should be used in conjunction with the *General technical guidelines for the environmentally sound management of wastes consisting of, containing or contaminated with persistent organic pollutants)*" (UNEP, 2015) (hereinafter referred to as "general technical guidelines"). The general technical guidelines are intended to serve as an umbrella guide for the ESM of wastes consisting of, containing or contaminated with persistent organic pollutants (POPs) and provide more detailed information on the nature and incidence of wastes consisting of, containing or contaminated with HBCD for purposes of their identification and management.

4. In addition, the *Technical guidelines on the environmentally sound management of wastes consisting of, containing or contaminated with hexabromodiphenyl ether and heptabromodiphenyl ether, or tetrabromodiphenyl ether and pentabromodiphenyl ether (POP-BDEs)* (UNEP, 2015a) are relevant to those cases where HBCD is present in waste electrical and electronic equipment (WEEE).

B. Description, production, use and wastes

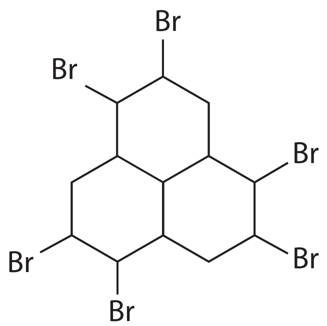
1. Description

5. HBCD 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.

6. 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).

7. 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 (see figure 1 below). 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.

Figure 1: Structural formula of HBCD



[1] Decisions BC-11/3 and BC-12/3 of the Conference of the Parties to the Basel Convention on the Control of Transboundary Movements of Hazardous Wastes and Their Disposal; decision OEWG-9/3 the Open-ended Working Group of the Basel Convention; and decisions SC-6/11 and SC-6/13 of the Conference of the Parties to the Stockholm Convention on Persistent Organic Pollutants.

8. 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.

9. HBCD is used solely as an additive in physical admixtures with host polymers and can migrate within solid matrices and volatilize from the surface of articles during their service lives (Posner et al, 2010; ECHA, 2009; European Commission, 2008). HBCD may be released from materials due to material abrasion, but releases from polystyrene foams are low (UNEP/POPS/POPRC.6/13/Add.2). Additive flame retardants are physically combined with the materials that they treat and do not chemically bond with those materials like reactive flame retardants; as a result, they can migrate, at least in part, within and from their polymer matrices. A number of factors act to constrain the migration of HBCD within polymers, including its low vapour pressure, low water solubility and predicted high organic carbon-water partitioning coefficient. Nevertheless, some HBCD at the surface of polymers or products could be released into the environment during product use or disposal (Environment Canada and Health Canada, 2011; UNEP/POPS/POPRC.7/19/Add.1; the United States Environmental Protection Agency EPA, 2014).

10. HBCD is found to be widespread in the global environment, with elevated levels found in top predators in the Arctic. In biota, HBCD has been found to bioconcentrate, bioaccumulate and biomagnify at higher trophic levels. HBCD is well absorbed in rodent gastro-intestinal tracts. In humans, it is found in blood, plasma and adipose tissues. Measured and modelled data indicate that HBCD will undergo primary degradation under some conditions; however, ultimate degradation in the environment is expected to be a slow process (Environment Canada and Health Canada, 2011). The main transformation product of HBCD is 1,5,9-cyclododecatriene (CDT), which is formed through the step-wise reductive dehalogenation of HBCD (UNEP/POPS/POPRC.6/13/Add.2).

2. Production

11. Parties to the Stockholm Convention shall prohibit and/or eliminate the production of HBCD, unless they have notified the Secretariat of their intention to use it for expanded polystyrene (EPS) and extruded polystyrene (XPS) used in buildings in accordance with the time-limited specific exemption listed in Annex A to the Convention. In addition, parties for which the amendment did not enter into force automatically in 2014 may continue to produce HBCD for any purpose until they have ratified the amendment through which the chemical was listed in Annex A. Information on production of HBCD can be found in the register of specific exemptions of the Stockholm Convention on the Convention website (www.pops.int). Information on the status of ratification by the parties of the amendment listing HBCD in the Stockholm Convention can be found on the website of the Treaty Section of the United Nations (https://treaties.un.org/).

12. HBCD has been on the world market since the late 1960s and is still being produced for use in EPS and XPS in buildings. It has been produced mainly in China, the European Union (EU), Japan 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 EU countries and in the United States, and 18,000 tonnes in China (UNEP/POPS/POPRC.7/19/Add.1, UNEP/POPS/POPRC.8/16/Add.3). 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 and UNEP/POPS/POPRC.8/16/Add.3).

13. HBCD was the only technically feasible flame retardant for “one-step” flame-retardant EPS raw material production processes until around 2014, when alternatives became available in significant amounts. The “one-step” production process is prevalent in Europe and has for the most part replaced the less economical “two step” production process, which could involve the use of flame retardants other than HBCD (EPA, 2014).

3. Use

14. Parties to the Stockholm Convention shall prohibit and/or eliminate the use of HBCD, except if they have notified the Secretariat of their intention to use it for EPS and XPS used in buildings in accordance with the time-limited use exemption listed in Annex A to the Convention. Parties for which the amendment did not enter into force automatically in 2014 may continue to produce HBCD for any purpose until they have ratified the amendment through which the chemical was listed in Annex A. Information on the use of HBCD under this exemption can be found in the register of specific exemptions of the Stockholm

Convention on the Convention website (www.pops.int). Information on the status of ratification by the parties of the amendment listing HBCD in the Stockholm Convention can be found on the website of the Treaty Section of the United Nations (https://treaties.un.org/).

15. Most HBCD is used to reduce the flammability of EPS and XPS foams and textiles. It is 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). Outside the construction sector, polystyrene (PS) foams are also used to insulate coolers, as a packaging material, decorations and ornaments, although these applications are usually not intended to be flame retarded. The use of flame retardant in the EPS for these applications depends on local requirements, as well as the quality of EPS raw material that may be available (logistical reasons). HBCD is not used in food packaging according to an EU technical report (ECHA, 2009), but flame-retardant EPS has been found in packaging materials as well (EUMEPS, 2009).

16. The use of flame retardant EPS and XPS insulation varies significantly between countries, depending on local building codes and fire safety regulations. Due to their high volumes and bulky sizes and the costs associated with transporting them, PS foam insulation materials are usually tailor made for local markets and produced mostly for local consumption rather than export (Posner et al, 2010; BSEF, 2011). In some countries, virtually all EPS and XPS are flame retardant, while in other countries only flame-retardant-free EPS and XPS are used. The concentrations at which HBCD is used depend on the polymer it is used with and on the fire safety requirements the products must meet (UNEP/POPS/POPRC.7/19/Add.1); concentrations will also vary from country to country. Typical concentrations of HBCD in different materials are shown in table 1 below.

Table 1: Typical concentrations of HBCD in different materials

Flame-retardant materials	HBCD content (in mg/kg)
Expanded polystyrene (EPS)	5,000-10,000[2]
Extruded polystyrene (XPS)	8,000-25,000[3]
Textile back-coatings	60,000-150,000[4]
Textiles	22,000-43,000[5]
High-impact polystyrene (HIPS)	10,000-70,000[6]

17. A less common application of HBCD is its use as a flame retardant in textiles and textile back-coatings for use in residential and commercial upholstered furniture, transportation seating, curtains, wall coverings and draperies. Textiles can be treated with flame retardants through fabric impregnation or spraying or by spinning flame-retardant polymers into textile yarns. The concentrations of HBCD used in the production of flame-retardant textiles are much higher than those used in PS foam production.

18. Other minor uses of HBCD include its use as an additive in adhesives and paints and high-impact polystyrene (HIPS) for electrical and electronic equipment so as to make them flame retardant. HBCD has been largely replaced with other flame retardants in these applications.

19. The majority 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/POPS/POPRC.7/19/Add.1, UNEP/POPS/POPRC.8/16/Add.3).

4. Wastes

20. Action aimed at waste streams of importance in terms of volume and concentration will be essential to eliminating, reducing and controlling the environmental load of HBCD from waste management activities. In that context, the following should be recognized:

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

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

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

5 Kajiwara et al., 2009.

6 ECHA, 2009 (UNEP/POPS/POPRC.7/19/Add.1).

(a) The main use of HBCD globally has been as a flame retardant in EPS and XPS foams for use in insulation and construction (with more than 90 per cent of HBCD used for this purpose), while its use in textile applications and in high impact polystyrene (HIPS) used in electric and electronic appliances has been less significant (BSEF, 2011; UNEP/POPS/POPRC.6/13/Add.2 and references therein, including ECHA, 2009, OECD, 2007, INE-SEMARNAT, 2004, LCSP, 2006 and BSEF, 2010). The available assessments estimate the environmental emissions of HBCD during production and chemical use to be small, compared to other phases of the lifecycle, i.e. the releases from products and waste (European Commission, 2008). The losses from EPS raw material production may, however, be high unless the HBCD chemical packaging materials (bags) are properly managed and unless emission reduction measures and use of best available technology (BAT) and best environmental practices (BEP) are in place (UNEP/POPS/POPRC.6/13/Add.1 and Add.2). Releases from processing of PS foams are expected to be much lower than those associated with the application of HBCD containing back coat to textiles (ECHA, 2009);

(b) There are releases of HBCD from products and articles (European Commission, 2008; Miyake et al., 2009; Kajiwara et al., 2009), but the estimates concerning releases during consumer use of products are highly uncertain (ECHA, 2009). Releases from polystyrene foams are low (UNEP/POPS/POPRC.6/13/Add.2) because HBCD is incorporated in the plastic polymer matrix, which prevents migration and exposure via surface contact. However, the use of HBCD as a flame-retardant additive in textiles could possibly lead to contamination of surface-water during washing of the fabric. Furthermore, emissions due to the wear of the fabric during its service life can also be expected (European Commission, 2008);

(c) Due to the long service lives of products where HBCD has mainly been used, waste management is a potentially growing source of HBCD environmental releases. There may be some releases of HBCD in dusts, when buildings insulated with flame-retardant insulation materials are demolished, but future emissions from construction sites (e.g., during repair or demolition of old buildings, roads, railway and other structures) will depend on the demolition techniques used (European Commission, 2008);

(d) HBCD may also be released during industrial and municipal wastewater discharges to surface waters and through leachate from landfills. There is little information on the quantities of HBCD in landfill leachates; however, given the low water solubility of HBCD, it is believed that HBCD releases from the surfaces of polymer products in landfills is limited (Environment Canada and Health Canada, 2011.

21. Wastes may contain variable concentrations of HBCD, depending on the quantities in which HBCD was originally present in specific products and the quantities released during product use and end-of-life management. The concentrations of HBCD in insulation foams are, however, expected to remain stable due to assumed low HBCD emissions during the service lives of such foams (ECHA, 2009). Waste pure HBCD and waste HBCD mixtures constitute a small fraction of the total wastes consisting of, containing or contaminated with HBCD (hereinafter referred to as "HBCD wastes") (UNEP/POPS/POPRC.7/19/Add.1). Articles containing HBCD may become construction waste, waste electrical and electronic equipment (WEEE), textile waste, furniture waste, waste vehicles or household waste. HBCD wastes may be found in:

(a) HBCD chemical:

(i) Pure HBCD;

(ii) Obsolete HBCD, which can no longer be used;

(b) HBCD mixtures:

(i) EPS beads;

(ii) XPS masterbatches;

(iii) Textile back-coatings;

(iv) Paints, adhesives and latex binders;

(c) HBCD mixture packaging materials:

(i) HBCD packing;

(ii) HBCD mixture packaging;

(d) HBCD-containing articles:

(i) XPS and EPS insulation boards;

(ii) Waste from PS foam production (cutting waste, etc.);

(iii) Construction and demolition waste (insulation boards used in foundation, walls and ceilings, ground deck, parking deck, etc.);

(iv) Packaging materials made of PS foams;

(v) Ornaments and decorations;

(vi) EPS loose filling used in furniture (beanbags, sofas);

(vii) Housing (HIPS) and wirings in electronic and electrical equipment;

(viii) Flame retardant textiles (protective clothing, carpets, curtains, upholstered fabrics, tents, the interiors of public transportation conveyances (e.g., automobiles, trains, aircraft, etc.) and other technical textiles);

(ix) Automotive parts;

(e) Municipal and industrial sludge and landfill leachate.

22. Insulation boards form the majority of HBCD wastes. HBCD wastes present a specific challenge to waste management because of the long service lives of some of the articles that contain HBCD. For instance, the lifespan of PS foam insulation in buildings is reported to be 30-50 years (ECHA, 2009; Posner et al, 2010) and could exceed 100 years. The use of HBCD in insulation boards and its presence in buildings and other structures has been increasing since the 1980s, so it is likely that releases from EPS and XPS from waste materials will become more significant in the future, especially from around 2025, when an increasing number of buildings containing HBCD are expected to be refurbished or demolished (UNEP/POPS/POPRC.6/13/Add.2). This turn-over will be different in different regions of the world.

23. The most important HBCD waste streams in terms of potential volume are expected to be:

(a) Insulation boards (more than 90 per cent of the HBCD is used for flame-retardant EPS and XPS foams used for insulation and construction (UNEP/POPS/POPRC.7/19/Add.1));

(b) Textile waste from upholstery in cars and other vehicles and commercial buildings, e.g., from recycling and maintenance;

(c) Furniture waste in countries where flame-retardant EPS and textiles have been used; and

(d) Packaging materials made of flame-retardant PS foams.

24. The most important HBCD waste streams in terms of potential releases or concentration of HBCD are expected to be:

(a) HBCD chemical waste;

(b) Waste from HBCD production (in the few countries where HBCD is still produced);

(c) Packages used for HBCD chemical and mixtures;

(d) Textile waste from upholstery in cars and other vehicles and from commercial buildings, e.g., from recycling and maintenance;

(e) WEEE and solid wastes from disposal of such waste; and

(f) HBCD mixtures (EPS beads, XPS masterbatches, textile back-coatings).

25. HBCD wastes can be generated in a diverse range of applications, at different stages of the HBCD life cycle and through different release media. Knowledge of release media guides the analysis and choice of methods that may be used to manage such wastes. Table 2 provides an overview of relevant information regarding the life cycle of HBCD wastes.

Table 2: Overview of the production and application of HBCD and their release media into the environment (Based on UNEP/POPS/POPRC.6/13/Add.2 and UNEP/POPS/POPRC.7/19/Add.1)

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 (UNEP/POPS/POPRC.7/19/Add.1)).				
HBCD 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 back-coatings	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, antimony trioxide, HBCD	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.)				

EPS articles	EPS beads	Expansion and molding	Flame-retardant EPS insulation, including insulation boards: 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	• 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[7]	
			Other molded EPS articles, such as ornaments, decorations, logos, 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
Textiles	Flame-retardant textiles (back-coating 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

7 EPS packaging is not usually made of flame-retardant EPS unless specifically required or due to logistical reasons, e.g., when the only available EPS raw materials are flame-retardant.

II. Relevant provisions of the Basel and Stockholm conventions

A. Basel Convention

26. Article 1 ("Scope of the Convention") defines the waste types subject to the Basel Convention. Subparagraph 1 (a), of that Article sets forth a two-step process for determining if a "waste" is a "hazardous waste" subject to the Convention. First, the waste must belong to any category contained in Annex I of the Convention ("Categories of wastes to be controlled"). Second, the waste must possess at least one of the characteristics listed in Annex III of the Convention ("List of hazardous characteristics").

27. Annex I and II lists some of the wastes which may consist of, contain or be contaminated with HBCD:

(a) Y12: Wastes from production, formulation and use of inks, dyes, pigments, paints, lacquers, varnish;

(b) Y13: Wastes from production, formulation and use of resins, latex, plasticizers, glues/adhesives;

(c) Y17: Wastes resulting from surface treatment of metals and plastics;

(d) Y18: Residues arising from industrial waste disposal operations;

(e) Y45: Organohalogen compounds other than substances referred to in this Annex (e.g. Y39, Y41, Y42, Y43, Y44);

(f) Y46: Wastes collected from households.

28. Annex I wastes are presumed to exhibit one or more Annex III hazard characteristics, which may include H6.1 "Poisonous (acute), H11 "Toxic (delayed or chronic)"; H12 "Ecotoxic"; or H13 (capable after disposal of yielding a material which possess a hazardous characteristic)", unless, through "national tests," they can be shown not to exhibit these characteristics. National tests may be useful for identifying a particular hazard characteristic in Annex III of the Convention until such time as the hazardous characteristic is fully defined. For example, tests of both EPS and XPS boards conducted by the industry in line with the UK Environmental Agency Technical Guidance WM2 (Hazardous waste: Interpretation of the definition and classification of hazardous waste) concluded that EPS and XPS foam boards that contain HBCD need not be classified as hazardous waste (HBCD in Polystyrene Foams: Product Safety Assessment 2013). Guidance papers for Annex III hazardous characteristics H11, H12 and H13 were adopted on an interim basis by the Conference of the Parties to the Basel Convention at its sixth and seventh meeting.

29. List A of Annex VIII describes wastes that are "characterized as hazardous under Article 1, paragraph 1 (a) of this Convention" although "their designation on this Annex does not preclude the use of Annex III [hazard characteristics] to demonstrate that a waste is not hazardous" (Annex I, paragraph (b)). List A of Annex VIII includes a number of wastes or waste categories that have the potential to contain or be contaminated with HBCD, including:

(a) A1180: Waste electrical and electronic assemblies or scrap containing components such as accumulators and other batteries included on list A, mercury-switches, glass from cathode-ray tubes and other activated glass and PCB-capacitors, or contaminated with Annex I constituents (e.g. cadmium, mercury, lead, polychlorinated biphenyl) to an extent that they possess any of the characteristics contained in Annex III (note the related entry on list B B1110);

(b) A3050: Wastes from production, formulation and use of resins, latex, plasticizers, glues/adhesives excluding such wastes specified on list B (note the related entry on list B B4020);

(c) A3120: Fluff – light fraction from shredding;

(d) A4070: Wastes from the production, formulation and use of inks, dyes, pigments, paints, lacquers, varnish excluding any such wastes specified on list B (note the related entry on list B B4010);

(e) A4130: Waste packages and containers containing Annex I substances in concentration sufficient to exhibit Annex III hazard characteristic;

(f) A4140: Waste consisting of or containing of specification or outdated chemicals corresponding to Annex I categories and exhibiting Annex III hazard characteristics;

(g) A4160: Spent activated carbon not included on list B (note the related entry on list B B2060).

30. List B of Annex IX lists wastes that will not be wastes covered by Article 1, paragraph 1 (a), unless they contain Annex I material to an extent causing them to exhibit an Annex III characteristic. List B of Annex IX includes a number of wastes or waste categories that have the potential to contain or be contaminated with HBCD, including:

(a) B1110: Electrical and electronic assemblies:

(i) Electronic assemblies consisting only of metals or alloys

(ii) Waste electrical and electronic assemblies or scrap[8] (including printed circuit boards) not containing components such as accumulators and other batteries included on list A, mercury-switches, glass from cathode-ray tubes and other activated glass and PCB-capacitors, or not contaminated with Annex I constituents (e.g., cadmium, mercury, lead, polychlorinated biphenyl) or from which these have been removed, to an extent that they do not possess any of the characteristics contained in Annex III (note the related entry on list A A1180)

(iii) Electrical and electronic assemblies (including printed circuit boards, electronic components and wires) destined for direct reuse and not for recycling or final disposal;

(b) B1250: Waste end-of-life motor vehicles, containing neither liquids nor other hazardous components;

(c) B3010: Solid plastic waste;[9]

(d) B3030: Textile wastes;[10]

(e) B3035: Waste textile floor coverings, carpets;

(f) B4010: Wastes consisting mainly of water-based/latex paints, inks and hardened varnishes not containing organic solvents, heavy metals of biocides to an extent to render them hazardous (note the related entry on list A A4070);

(g) B4020: Wastes from production, formulation and use of resins, latex, plasticizers, glues/adhesives, not listed on list A, free of solvents and other contaminants to an extent that they do not exhibit Annex III characteristics, e.g. water-based, or flues based on casein, starch, dextrin, cellulose ethers, polyvinyl alcohols (note the related entry on list A A3050).

31. For further information, see section II.A of the general technical guidelines.

B. Stockholm Convention

32. The present guidelines cover intentionally-produced HBCD, whose production and use are to be eliminated in accordance with Article 3 and part I of Annex A to the Stockholm Convention.

33. Part VII of Annex A to the Stockholm Convention outlines specific requirements for HBCD-containing products manufactured under the exemption, as follows:

"Each party that has registered for the exemption pursuant to Article 4 for the production and use of hexabromocyclododecane 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."

34. Further information on the register of specific exemptions for HBCD is available from: www.pops.int.

35. For further information, see section II.B of the general technical guidelines.

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8 This entry does not include scrap from electrical power generation.

9 Refer to Annex IX of the Basel Convention for a full description of this entry.

10 Ibid.

III. Issues under the Stockholm Convention to be addressed cooperatively with the Basel Convention

A. Low POP content

36. The provisional definition of low POP content for HBCD is 100 mg/kg or 1000 mg/kg.[11]

37. The low POP content described in the Stockholm Convention is independent from the provisions on hazardous waste under the Basel Convention.

38. Wastes with a content of HBCD above 100 mg/kg or 1000 mg/kg[12] must be disposed of in such a way that the POP content is destroyed or irreversibly transformed in accordance with the methods described in subsection IV.G.2. Otherwise, they may be disposed of in an environmentally sound manner when destruction or irreversible transformation does not represent the environmentally preferable option in accordance with the methods described in subsection IV.G.3.

39. Wastes with a content of HBCD at or below 100 mg/kg or 1000 mg/kg should be disposed of in accordance with the methods referred to in subsection IV.G.4 of the general technical guidelines (outlining disposal methods when POP content is low), taking into account section IV.I.1 below (pertinent to higher-risk situations).

40. For further information on low POP content, refer to section III.A of the general technical guidelines.

B. Levels of destruction and irreversible transformation

41. For the provisional definition of levels of destruction and irreversible transformation, see section III.B of the general technical guidelines.

C. Methods that constitute environmentally sound disposal

42. See section IV.G below and section IV.G of the general technical guidelines.

IV. Guidance on environmentally sound management (ESM)

A. General considerations

43. For further information, see section IV.A of the general technical guidelines.

B. Legislative and regulatory framework

44. Parties to the Basel and Stockholm conventions should examine their national strategies, policies, controls, standards and procedures to ensure that they are in agreement with the two conventions and their obligations under them, including those that pertain to ESM of HBCD waste.

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[11] Determined according to national or international methods and standards. It is noted that further work to agree on one value will be undertaken according to decision BC-12/3.

[12] *Ibid.*

45. Elements of a regulatory framework applicable to HBCD should include measures to prevent the generation of wastes and to ensure the environmentally sound management of generated wastes. Such elements could include:

(a) Environmental protection legislation establishing a regulatory regime, setting release limits and establishing environmental quality criteria;

(b) Prohibitions on the production, sale, use, import and export of HBCD, except in the case of parties that have notified the Secretariat of their intention to use or produce HBCD in accordance with the time-limited specific exemption listed in Annex A to the Stockholm Convention;

(c) A requirement that best available technologies (BAT) and best environmental practices (BEP) be employed in the production and use of HBCD, in cases where parties have notified the Secretariat of their intention to use or produce HBCD in accordance with the time-limited exemption listed in Annex A to the Stockholm Convention;

(d) Measures to ensure that HBCD waste cannot be disposed of in ways that that may lead to recovery, recycling, reclamation, direct reuse or alternative uses of HBCD;

(e) Adequate ESM controls to separate HBCD-containing materials from materials that can be recycled (e.g., non-HBCD containing insulation and packaging materials, textiles and materials made with alternative flame retardants);

(f) Measures necessary to ensure that HBCD-containing EPS and XPS can be easily identified throughout their life cycles through labelling or other means, in cases where parties have notified the Secretariat of their intention to use or produce HBCD in accordance with the time-limited specific exemption listed in Annex A to the Stockholm Convention;

(g) Transportation requirements for hazardous materials and waste;

(h) Specifications for containers, equipment, bulk containers and storage sites for HBCD chemical waste;

(i) Specification of acceptable analytical and sampling methods for HBCD;

(j) Requirements for waste management and disposal facilities;

(k) Definitions of hazardous waste and conditions and criteria for the identification and classification of HBCD wastes as hazardous wastes;

(l) A general requirement for public notification and review of proposed government waste-related regulations, policies, certificates of approval, licences, inventory information and national releases and emissions data;

(m) Requirements for identification, assessment and remediation of contaminated sites;

(n) Requirements concerning the health and safety of workers; and

(o) Legislative measures on, e.g., waste prevention and minimization, inventory development and emergency response.

46. For further information, see section IV.B of the general technical guidelines.

C. Waste prevention and minimization

47. Both the Basel and Stockholm conventions advocate waste prevention and minimization. The production and use of HBCD are to be eliminated under the Stockholm Convention, unless they fall under the exemptions listed in part I of Annex A to the Convention.

48. Quantities of waste containing HBCD should be minimized through isolation and separation of those wastes from other wastes at source in order to prevent their mixing with, and contamination of, other waste streams.

49. The mixing and blending of wastes with HBCD content above 100 mg/kg or 1000 mg/kg with other materials solely for the purpose of generating a mixture with an HBCD content at or below 100 or

1000 mg/kg are not environmentally sound. Nevertheless, the mixing or blending of materials as a pre-treatment method may be necessary in order to enable treatment or to optimize treatment efficiency.

50. For further information, see section IV.C on waste prevention and minimization of the general technical guidelines.

D. Identification of wastes

51. Article 6, paragraph 1 (a), of the Stockholm Convention requires each party to, *inter alia,* develop appropriate strategies for the identification of products and articles in use and wastes consisting of, containing or contaminated with POPs. The identification of HBCD wastes is the starting point for their effective ESM.

52. For general information on identification and inventories, see section IV.D of the general technical guidelines.

1. Identification

53. HBCD wastes can be found in the following stages of the HBCD life cycle:

(a) HBCD manufacturing and processing:

(i) Waste generated from the production and processing of HBCD

(ii) In water, soil or sediment close to manufacturing or processing sites;

(iii) Industrial wastewater and sludge;

(iv) Landfill leachate where chemical manufacturing or processing waste was disposed of;

(v) Stockpiles of unusable or unsellable material;

(b) Industrial applications of HBCD (EPS raw material and XPS foam production, textile production, furniture production, electronic and electrical equipment production):

(i) Residues generated from the application of HBCD;

(ii) In water, soil or sediments close to manufacturing or processing sites;[13]

(iii) Industrial wastewater and sludge;

(iv) Landfill leachate where waste from industrial applications was disposed of;

(v) Stockpiles of unusable or unsellable products;

(c) Industrial use of mixtures, products and materials containing HBCD (e.g., EPS foam production, furniture production, insulation board installation):

(i) Production and installation waste (cutting waste, leftovers, dust, etc.);

(ii) In water, soil or sediments close to sites where products were used;

(d) Use of products or articles containing HBCD:

(i) In water, soil or sediments close to sites where such products were used;

(e) Disposal of products or articles containing HBCD:

(i) In certain facilities for the collection, recycling and recovery of textiles, PS foams, electronic and electrical equipment, and vehicles;

(ii) In municipal landfill leachate;

(iii) In municipal wastewater and sludge.

[13] Li et al, 2012.

54. It should be noted that even experienced technical personnel may not be able to determine the nature of an effluent, substance, container or piece of equipment by its appearance or markings. Consequently, parties may find the information on production, use and types of waste provided in section I.B of the present guidelines useful in identifying articles and mixtures containing HBCD.

55. Currently, articles and products can be found on the market that either contain HBCD or alternative flame retardants or contain no flame retardants, depending on applicable fire safety requirements, building codes and the types of EPS raw materials available on the market. It is not possible to distinguish between HBCD-containing and non-HBCD containing EPS, XPS, textiles or furniture on the basis of visual appearance alone. It is useful to have knowledge of past and current fire safety requirements.

56. In cases where EPS and XPS are produced under the specific exemption listed in Annex A to the Stockholm Convention, the Convention provides that parties shall take the necessary measures to ensure that HBCD-containing EPS and XPS are easily identifiable through labelling or other means throughout their life cycles.

57. X-ray fluorescence (XRF) analysis can be used as an inexpensive and rapid screening method to determine whether a material contains bromine. The presence of bromine in PS-based articles produced before 2014 often indicates the presence of HBCD. Brominated flame retardants other than HBCD may have been used to enhance PS fire safety in the so-called "two-step" production process, a rare process that appears to be in use only in the United States. In those cases, since both HBCD and the flame retardants used in the two-step process contain bromine, XRF will not be useful for distinguishing between products containing HBCD and products containing other flame retardants

2. Inventories

58. When developing an inventory, it is important to consider the service life of the articles and when they have been placed on the market. Whether HBCD has been used in articles largely depends on local regulations and practices (current and historical), and it may be possible to identify the times when flame-retardants has been required for the uses of the articles. As most flame retardant EPS and XPS has been produced with HBCD until recently, it significantly impacts the volumes of POPs waste.

59. PS foam insulation materials and certain textiles have a very long service life, and will enter the waste stage decades after they were introduced on the market. Their presence depends on the local fire-safety regulations at the time of construction or placing on the market. Also electrical and electronic equipment have a relatively long service life, but HBCD has been mainly replaced by other chemicals and the majority of those articles may already have been disposed of (UNEP/POPS/POPRC.7/19/Add.1). The same applies with packaging materials, which have a short service life, but generally do not contain HBCD. However, they may have already contaminated recycling streams.

60. The first step that should be taken when developing HBCD inventories is the identification of the types of industries that may have been producing HBCD or using it in the production of mixtures or articles. Inventories should, as appropriate, be based on information on:

(a) Production of HBCD within a country;

(b) Imports and exports of products and articles containing HBCD;

(c) Use of articles containing HBCD in the country;

(d) Current and past regulatory requirements (e.g., building codes, fire safety requirements) regarding the use of insulation materials and textiles which would help to establish whether it is likely that materials produced at a given time contain HBCD;

(e) Disposal of HBCD wastes, including possible recycling into new or non-flame- retardant products;

(f) Imports and exports of HBCD wastes.

61. The preparation of inventories requires cooperation between those producing the inventories and relevant actors, such as fire safety and building authorities; possible producers of HBCD, HBCD mixtures or formulations; HBCD downstream users producing articles containing HBCD; customs officials; personnel at waste disposal and recycling facilities; and national focal points under the Basel and Stockholm

conventions. In some cases, government regulations may be required to ensure those who hold HBCD wastes report their holdings and cooperate with government inspectors.

62. Recognizing that it is likely that the majority of HBCD is found in insulation in the construction sector, analysing historical regulatory measures governing the use of flame retardants in that sector, as well as building practices, should help provide a sense of the magnitude of the inventory effort required and help to narrow down the number of possible holders of HBCD wastes. If HBCD has been produced in or imported into a country for use in the formulation of HBCD mixtures, the companies involved may be able to give estimates or exact figures of the timeframes and amounts of HBCD used in domestic applications and should be involved in the preparation of inventories.

63. Although HBCD has been on the world market since the 1960s, its use has grown over the last few decades in response to national fire safety requirements requiring the use of flame retardants. Even in cases where such requirements do not exist, flame-retardant materials may be used due to logistical reasons, i.e., when the only available raw materials for certain articles are flame-retardant.

64. The volumes of HBCD flame-retardant articles imported and exported globally are largely unknown.

E. Sampling, analysis and monitoring

65. For general information on sampling, analysis and monitoring, see section IV.E of the general technical guidelines.

66. Specifically for articles that potentially contain HBCD, the sampling, analysis and monitoring procedures should be described in conjunction with waste collection and waste handling processes, which are waste category specific.

1. Sampling

67. Sampling serves as an important element for identifying and monitoring environmental concerns and human health risks.

68. Standard sampling procedures should be established and agreed upon before the start of the sampling campaign. Sampling should comply with specific national legislation, where it exists, or with international regulations and standards. Currently, there is no standardized method for sampling of HBCD in articles, such as foams, furniture and textiles.

69. For buildings, based on an analysis of fire safety requirements and building codes at the time of construction or renovation of a building or the placing on the market of building materials, it can be determined whether such materials are likely to contain HBCD. In such cases sampling may not be necessary. If the data required to conduct such analyses are not available, and in cases where it might be appropriate to prove that PS foam boards in a given building do not contain HBCD, sampling before building demolition is recommended to determine the presence of HBCD. Sampling of different building parts (e.g., facade, flooring, etc.) may also be necessary. With regard to WEEE, *Technical Specification (TS): 50625-3-1 Collection, logistics & treatment requirements for WEEE*, currently under development in Europe, is expected to describe a sampling method for WEEE.

70. Types of matrices that are typically sampled for HBCD include:

(a) Liquids:

(i) Leachate from dumpsites and landfills;

(ii) Water (surface water and groundwater, drinking water, and industrial and municipal effluents);

(iii) Biological fluids (blood, in the case of worker health monitoring);

(b) Solids:

(i) Sewage sludge;

(ii) Biological samples (adipose tissue);

(iii) Stockpiles of HBCD, mixtures and articles consisting of, containing or contaminated with HBCD;

(iv) Indoor dust;

(c) Gases:

(i) Air (indoor and outdoor);

(ii) Exhaust gas.

2. Analysis

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

72. The development and dissemination of reliable analytical methods and the accumulation of high-quality analytical data are important to understand the environmental impact of hazardous chemicals, including POPs.

73. Total HBCD (i.e., the sum of all HBCD isomers) can be analyzed with gas chromatography-mass spectrometers (GC-MS), liquid chromatography-mass spectrometers (LC-MS) and high performance liquid chromatography-mass spectrometers (HPLC-MS). HPLC-MS can also serve to identify individual HBCD isomers. Gas chromatography-flame ionization detectors (GC-FID) using a reference HBCD are also able to identify and quantify HBCD. A number of analytical methods for analysing HBCD in environmental samples and in foams have been developed, but none has yet been internationally standardized. The accuracy as well as comparability especially at low levels may be questioned until standard methods will become available. For the analysis of HBCD in plastics used for electrical products, standard IEC 62321-6 'Determination of certain substances in electrotechnical products - Part 6: Determination of polybrominated biphenyls and polybrominated diphenyl ethers in polymers and electronics by GC-MS, IAMS and HPLC-UV' can be applied. Analyzing HBCD in articles, such as furniture, should be further developed.

74. Laboratory analyses are not a practicable means of determining the presence of HBCD in materials and articles that have become waste, as they are too expensive and time-consuming. At present, there are fast and inexpensive screening methods that can serve to determine the presence of bromine in materials and articles; the presence of bromine can be seen as an indicator that HBCD is present in EPS and XPS articles placed on the market before 2014 in countries where HBCD was the only flame retardant used in PS foams. Methods are available for analysing HBCD in WEEE, but not in textiles.

3. Monitoring

75. Monitoring and surveillance serve as elements for identifying and tracking environmental concerns and human health risks. Information collected from monitoring programmes feeds into science-based decision-making processes and is used for the evaluation of the effectiveness of risk management measures, including regulations.

76. Monitoring programmes should be implemented in facilities managing HBCD and HBCD wastes.

F. Handling, collection, packaging, labelling, transportation and storage

77. For general information on handling, collection, packaging, labelling, transportation and storage, see section IV.F of the general technical guidelines. *Technical Specification (TS) 50625-3-1 Collection, logistics & treatment requirements for WEEE*, currently under development in Europe, is expected to describe waste management processes for WEEE.

1. Handling

78. Organizations handling waste pure HBCD and waste HBCD mixtures should have in place a set of procedures for handling such wastes and workers should be trained in such procedures.

79. HBCD is commonly found in household dust, environmental samples and indoor air in houses and transportation vehicles, although there is no information on the quantities of HBCD released from these sources.

80. If polystyrene compaction to reduce waste volume takes place, appropriate measures should be taken to protect human health and the environment from exposure to HBCD released from degraded polymers. In the handling of HBCD wastes, care should be taken to avoid environmental releases of HBCD from articles due to breakage or damage to article integrity.

81. The waste streams containing HBCD should be kept separated from those waste streams that do not contain HBCD, although they may visually look the same, to facilitate environmentally sound waste management (for instance, buildings may contain both flame retardant and non-flame retardant insulation materials). Only in cases where non-HBCD containing waste is managed according to section IV.G of the general technical guidelines separation is not necessary.

2. Collection

82. Collection arrangements that include depots for HBCD chemical waste should provide for the separation of HBCD wastes from other wastes.

83. HBCD wastes like insulation materials, packaging materials and textile waste containing HBCD should be collected separately from wastes that do not contain HBCD., unless the waste is incinerated or otherwise managed according to section IV.G of the general technical guidelines.

84. Waste electrical and electronic equipment (WEEE) may contain high-impact-polystyrene (HIPS) containing HBCD. For further information, see section IV.F.2 of the POP-BDEs technical guidelines (UNEP, 2015a). *Technical Specification (TS) 50625-3-1: Collection, logistics & treatment requirements for WEEE*, currently under development in Europe, is expected to describe a sampling method for WEEE.

85. Collections depots should not become long-term storage facilities for HBCD wastes.

3. Packaging

86. HBCD, HBCD packaging, HBCD mixture wastes and compacted polystyrene foams containing HBCD should be properly packaged before storage for ease of transport and as a safety measure to reduce the risk of leaks and spills.Articles containing HBCD typically are consumer products and do not need specific packaging. If waste compaction takes place, however, appropriate measures should be taken to protect human health and the environment from exposure to HBCD.

4. Labelling

87. Every container carrying HBCD chemical waste should, as appropriate, be clearly labelled with a hazard warning label and a label providing details of the container and a unique serial number. Such details should include container contents (e.g., exact counts of equipment, volume, weight, type of waste carried), the name of the site from which the waste originated so as to allow its traceability, the date of any repackaging and the name and telephone number of the person responsible for the repackaging operation.

88. Waste streams containing HBCD should be clearly identified to facilitate their ESM. This is especially important in cases where both HBCD and non-HBCD articles are found. The Stockholm Convention provides that for EPS and XPS produced under the specific exemption listed in Annex A to the Stockholm Convention, parties are to take the necessary measures to ensure that EPS and XPS containing HBCD are easily identified through labelling or other means throughout their life cycles.

5. Transportation

89. Appropriate measures should be taken to prevent scattering or leakage of HBCD chemical wastes. Such wastes should be handled separately during transport to avoid their mixing with other materials.

6. Storage

90. HBCD wastes should be stored in designated sites and appropriate measures should be taken to prevent the scattering, release and underground seepage of HBCD, and to control the spread of odors.

91. Appropriate measures, such as the installation of partitions, should be taken to avoid contamination of other materials and wastes with HBCD.

92. Storage areas for HBCD wastes should have adequate access roads for vehicles.

93. Large amounts of HBCD wastes in storage should be protected from fire, as those wastes are often inherently flammable.

G. Environmentally sound disposal

1. Pre-treatment

94. For information, see subsection IV.G.1 of the general technical guidelines. If compaction of HBCD waste takes place as a pre-treatment prior to disposal, appropriate measures should be taken to protect human health and the environment from exposure to HBCD. Compaction may also cause releases of other unwanted substances, e.g., ozone-depleting substances used as blowing agents in the production of some foams.

2. Destruction and irreversible transformation methods

95. Destruction and irreversible transformation methods for the environmentally sound disposal of wastes with an HBCD content above 100 mg/kg or 1000 mg/kg[14] according to the general technical guidelines, at least:

(a) Cement kiln co-incineration;

(b) Hazardous waste incineration; and

(c) Advanced Solid waste incineration (ASWI).

96. It should be noted that PBDDs/PBDFs and PXDDs/PXDFs can be generated from the incineration of HBCD wastes (Mark et al, 2015).

97. For further information, see subsection IV.G.2 of the general technical guidelines.

3. Other disposal methods when neither destruction nor irreversible transformation is the environmentally preferable option

98. For further information, see subsection IV.G.3 of the general technical guidelines.

4. Other disposal methods when the POP content is low

99. For information, see subsection IV.G.4 of the general technical guidelines.

H. Remediation of contaminated sites

100. For information, see section IV.H of the general technical guidelines.

[14] *Ibid* 13.

I. Health and safety

101. For information, see section IV.I of the general technical guidelines.

1. Higher-risk situations

102. For general information, see subsection IV.I.1 of the general technical guidelines.

103. Higher-risk situations occur at sites where high concentrations of HBCD or high volumes of HBCD wastes are found and a high potential for exposure of workers or the general population exists. Direct dermal exposure to and inhalation of fine dust or particles containing HBCD in the workplace are of particular concern. For example, industrial workers at plants that produce EPS with HBCD have been found to have elevated levels of HBCD in their blood (UNEP/POPS/POPRC.6/13/Add.2). The application of recommended occupational safety measures is necessary to limit risks to workers (European Commission, 2008).

104. Potential higher-risk situations specific to HBCD may occur:

(a) HBCD chemical or mixtures production sites;

(b) At facilities producing EPS raw materials, XPS masterbatches and textile back-coatings;

(c) At building sites in which insulation boards containing flame retardants are installed or demolished (UNEP/POPS/POPRC.6/13/Add.2) or PS foams are compacted and HBCD may be released in dust;

(d) At construction waste management facilities;

(e) At textile and furniture waste management facilities;

(f) At WEEE management facilities; and

(g) At waste vehicle management facilities.

2. Lower-risk situations

105. For information on lower risk situations, see subsection IV.I.2 of the general technical guidelines.

J. Emergency response

106. Emergency response plans should be in place at sites where HBCD chemical is produced (where allowed), used, stored, transported or disposed of. Further information on emergency response plans is given in section IV.J of the general technical guidelines.

K. Public participation

107. Parties to the Basel or Stockholm Convention should have open public participation processes. For further information see section IV.K of the general technical guidelines.

Annex to the technical guidelines

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