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on Persistent Organic
Pollutants**

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**Report of the Persistent Organic Pollutants Review Committee
on the work of its seventh meeting**

Addendum

Risk management evaluation on hexabromocyclododecane

At its seventh meeting, the Persistent Organic Pollutants Review Committee adopted a risk management evaluation on hexabromocyclododecane on the basis of the draft contained in document UNEP/POPS/POPRC.7/5, as amended. The text of the risk management evaluation is set out in the annex to the present addendum. It has not been formally edited.

Annex

Hexabromocyclododecane

RISK MANAGEMENT EVALUATION

14 October 2011

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Executive summary

1. Hexabromocyclododecane (HBCD; also HBCDD) was proposed as a POPs candidate by Norway in 2008. In 2010, the 6th meeting of the POPs Review Committee decided that HBCD is likely, as a result of its long-range environmental transport, to lead to significant adverse human health and environmental effects, such that global action is warranted. HBCD was considered by the Executive Body of the UNECE Convention on Long-Range Trans-boundary Air Pollution (LRTAP) to meet the criteria for POPs as defined under the POPs protocol.

2. HBCD is produced in China, Europe, Japan, and the USA. The current known annual production is approximately 28,000 tonnes per year (9,000 to 15,000 tonnes in China, 13,426 tonnes in Europe and the US). Available information suggests that use of HBCD may be rising. The main share of the market volume is used in Europe and China.

3. HBCD is used as a flame retardant additive, with the intent of delaying ignition and slowing subsequent fire growth during the service life of vehicles, buildings or articles, as well as while materials are stored. The main uses of HBCD are in flame-retarded expanded (EPS) and extruded (XPS) polystyrene foam for insulation and construction, with other uses in textile applications and electric and electronic appliances (high impact polystyrene/HIPS). In textiles, HBCD is used in back-coatings for upholstery and other interior textiles, including automotive applications. The volumes of HBCD flame retarded articles imported and exported globally are generally unknown.

4. Release of HBCD into the environment may occur during production and manufacturing, processing, transportation, use, handling, storage or containment, and from disposal of the substance or products containing the substance. Releases can be from point source discharges or diffuse releases from manufactured product usage, such as installation of insulation boards, use of flame retarded textiles or weathering and abrasion of flame retarded products in use. Several studies show the occurrence of HBCD in indoor air and house dust as well as in cabin dust in new and old cars. By-product polybrominated dioxins and furans can be released from uncontrolled combustion and incineration of the substance or products containing the substance.

5. The available assessments estimate the environmental emissions of HBCD during production and use to be small, compared to the releases from products and waste. HBCD emissions to indoor air from products made from EPS or XPS during service life when installed are estimated to be low, although the estimates concerning releases during consumer use of HBCD containing articles are highly uncertain.

6. Emissions from HBCD-containing materials will be a potential long-term source to the environment. Most of the produced volume of HBCD ends up in articles, mainly in polystyrene (XPS, EPS) used in the construction and building sector. The likely future emissions from such articles have not been assessed. The life span of polystyrene foam in buildings is reported to be 30-50 years. The use of HBCD in insulation boards and the HBCD built into buildings and constructions is increasing and it is likely that releases from EPS/XPS will be more significant in the future; particularly from about 2025 onwards, as increasing number of buildings containing HBCD retarded EPS and XPS will be refurbished or demolished. This turn-over will be different in different regions, and range from 10-50 years.

7. Wastes containing HBCD include production wastes, insulation boards, building and renovation wastes, and from other applications such as electrical and electronic products, textiles and transport vehicles. It is not known to what extent end-products containing HBCD are landfilled, incinerated, left in the environment or recycled. Waste ending up in the municipal waste streams is likely to be put in landfills or incinerated. In developing countries, electrical and electronic appliances containing HBCD and other toxic substances are often recycled under conditions which results in a relatively high release of HBCD to the environment and contamination of the sites and exposure of workers. Open burning and dump sites are common destinations for HBCD-containing articles and electronic wastes.

8. HBCD phase-out could include flame retardant substitution, resin/material substitution and product redesign. There are already available on the market chemical alternatives to replace HBCD in high-impact polystyrene (HIPS) and textile back-coating. The available non-halogenated chemical alternatives can be considered to be better for the environment and health. No alternative drop-in replacement chemical is currently available on the market for all EPS/ XPS production processes, although a substitute should become commercially available by 2012. In addition, other chemicals are under development in several regions by collaborative efforts between different stakeholders, but some time will still be needed before the identified alternatives can be phased in by the polystyrene foam

industry. There are also several alternative materials commercially available on the market that could be used as an alternative to flame retarded EPS and XPS. These include phenolic foams, glass and rock wool blankets, cellular glass, foam glass, and loose fills that may contain rock wool, fiber glass, cellulose or polyurethane foam. Another alternative used in some countries is to use EPS/XPS without flame retardants together with alternative construction techniques and thermal barriers. This option may, however, be subject to national building codes.

9. The suggested control measure is that HBCD be listed under the Convention. To allow for certain time-limited critical uses of HBCD, a specific exemption for use of HBCD in EPS/XPS could be given together with a description of the conditions for production and for these uses. Such a listing would effectively end the use of HBCD as a flame retardant in highly emissive textile applications and in HIPS, for which alternatives are widely available, and in EPS/XPS, when chemical drop-in substitutes are phased in.

1. Introduction

10. On June 18th 2008, Norway, as a Party to the Stockholm Convention, submitted a proposal to list the brominated flame retardant hexabromocyclododecane (HBCD; also HBCDD) as a possible Persistent Organic Pollutant (POP) under Annex A of the Convention (UNEP/POPS/POPRC.5/INF/16).

1.1 Chemical identity of the proposed substance

11. Commercial HBCD is a white solid substance. Producers and importers have provided information on this substance under two different names; hexabromocyclododecane (CAS number 25637-99-4, EC Number 247-148-4) and 1,2,5,6,9,10-hexabromocyclododecane (CAS number 3194-55-6, EC Number 221-695-9). HBCD was nominated under both names. The structural formula of HBCD is a cyclic ring structure with Br-atoms attached (Table 1). The molecular formula of the compound is $C_{12}H_{18}Br_6$ and its molecular weight is 641 g/mol. Depending on the manufacturer and the production method used, technical HBCD consists of 70-95 % γ -HBCD and 3-30 % of α - and β -HBCD (EC 2008; NCM 2008). Each of these stereoisomers has its own specific CAS number i.e. α -HBCD, CAS No: 134237-50-6; β -HBCD, CAS No: 134237-51-7; γ -HBCD, CAS No: 134237-52-8. Further information pertaining to the chemical identity of HBCD is listed in Table 2 and may be found in the supplementary information to the Risk Profile on HBCD (UNEP/POPS/POPRC.6/INF/25).

Table 1. Information pertaining to the chemical identity of HBCD

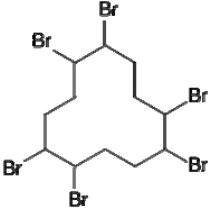
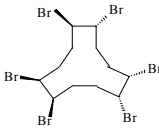
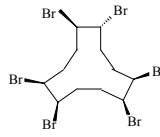
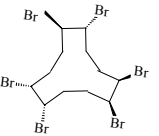
Chemical structure			
<p>Structural formula of HBCD¹:</p> <p>¹Structural formula for 1,2,5,6,9,10-HBCD, i.e., CAS no 3194-55-6. Note that CAS no 25637-99-4 is also used for this substance, although not correct from a chemical point of view as this CAS number does not specify the positions of the bromine atoms. As additional information, the structures and CAS numbers for the diastereomers making up 1,2,5,6,9,10-HBCD are given below, although these diastereomers always occur as mixtures in the technical product.</p>			
<p>Chiral components of commercial HBCD</p>	 <p>alpha-HBCD CAS No: 134237-50-6</p>	 <p>beta-HBCD CAS No: 134237-51-7</p>	 <p>gamma-HBCD CAS No: 134237-52-8</p>

Table 2. Chemical identity

Chemical identity	
Chemical Name:	Hexabromocyclododecane and 1,2,5,6,9,10 -hexabromocyclododecane
EC Number:	247-148-4; 221-695-9
CAS Number:	25637-99-4; 3194-55-6
IUPAC Name:	Hexabromocyclododecane
Molecular Formula:	C ₁₂ H ₁₈ Br ₆
Molecular Weight:	641.7
Trade names/ other synonyms:	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.
Stereoisomers and purity of commercial products:	Depending on the producer, technical grade HBCD consists of approximately 70-95% γ -HBCD and 3-30 % of α - and β -HBCD due to its production method (EC 2008). Each of these has specific CAS numbers. Two other stereoisomers, δ -HBCD and ϵ -HBCD have also been found by Heeb et al. (2005) in commercial HBCD in concentrations of 0.5 % and 0.3 %, respectively. These impurities are regarded as achiral at present. According to the same authors, 1,2,5,6,9,10-HBCD has six stereogenic centers and therefore, in theory, 16 stereoisomers could be formed.

12. HBCD has been on the world market since the late 1960s. Production has been reported in China, Europe, Japan, and the USA. The current known annual production is approximately 28,000 tonnes per year (China: 9,000 to 10,000 tonnes in 2009, and 15,000 tonnes in 2010; 13,426 tonnes by the BSEF member companies in Europe and the US in 2009). Japanese production data is not available. No information on production in other countries was received.

13. Based on responses from Parties and Observers, it appears that the main consumption and use of HBCD currently takes place in Europe and China. According to the global demand reported by the industry in 2001, more than half of the market volume (9,500 of 16,500 tonnes) was used in Europe. Total global demand for HBCD increased over 28% by 2002 to 21,447 tonnes, and rose again slightly in 2003 to 21,951 tonnes (BSEF 2006). In the US the sum of manufactured and imported HBCD was reported to lie between 4,540 to 22,900 tons in 2006 (US EPA 2010). The total volume of HBCD used in the EU was estimated to be about 11,580 tonnes in 2006. The demand of HBCD within the EU is bigger than the production there and the net import to the EU was estimated at 6,000 tonnes in 2006 (ECHA 2009). The authorities in Japan have reported the sum of domestic production and import of HBCD to be 2,844 tonnes in 2008 and 2,613 tonnes in 2009. Several other national authorities report an import of HBCD as a pure compound or in products; Canada (100-1,000 tonnes), Australia (<100 tonnes), Poland (500 tonnes imported from China annually), and Ukraine (UNEP/POPS/POPRC.6/13/Add.2). Available information suggests that use of HBCD may be rising (ECHA 2009; UNEP/POPS/POPRC.6/13/Add.2).

14. HBCD is used as an additive flame retardant in products, with the intent of delaying ignition and slowing subsequent fire growth during the service life of vehicles, buildings or articles, as well as while materials are stored (BSEF 2010; see UNEP/POPS/POPRC.6/13/Add.2 for overview). The main uses of HBCD globally are in flame-retardant expanded (EPS)¹ and extruded (XPS)² polystyrene foam for insulation and construction (more than 90% of the HBCD use), while the use in textile applications³ and electric and electronic appliances (high impact polystyrene/HIPS)⁴ is of a smaller scale (BSEF 2011, UNEP/POPS/POPRC.6/13/Add.2 and references therein e.g. ECHA 2009; OECD 2007; INE-SEMARNAT 2004; LCSP 2006; BSEF 2010). Using Inventory Update Reporting (IUR) data, the US EPA found that less than 1% of the total commercial and consumer use of HBCD in the US was for fabrics, textiles and apparel (US EPA 2010). HBCD is used in textile back-coating in

1 0.5-0.7 % HBCD w/w (Canada, PlasticsEurope/Exiba submission 2011)

2 0.8-2.5% HBCD w/w (BFRIP 2005, XPSA and CPIA, PlasticsEurope/Exiba submission 2011)

3 10-15% HBCD w/w (European Commission 2008)

4 1-7 % HBCD w/w (ECHA 2009)

furniture upholstery and other interior textiles, including applications in transport vehicles (Japan 2011; LCSP 2006). Some other minor uses have also been reported by KEMI (2006) and in UNEP/POPS/POPRC.6/13/Add.2.

15. Based on the responses from the Parties and Observers and ECHA (2009), the volumes of import and export of HBCD in flame retarded articles is generally unknown. Polystyrene foam materials are usually tailor made for the local market, and the main share of the production is for local consumption, and not exported (SWEREA 2010; BSEF 2011).

1.2. Conclusions of the Review Committee regarding Annex E information

16. At its sixth meeting in October 2010, the POPs Review Committee evaluated the draft risk profile for HBCD in accordance with Annex E (UNEP/POPS/POPRC.6/13) and adopted this (UNEP/POPS/POPRC.6/13/Add.2). The POPRC decided that, "HBCD is a synthetic substance with no known natural occurrence that continues to be used in many countries including in imported articles and products. Releases of HBCD to the environment are increasing in all regions investigated, i.e., Europe and in Asia (Japan). HBCD is persistent in the environment and bioaccumulates and biomagnifies in fish, birds and mammals. A number of measured levels in biota, including higher trophic levels such as birds and mammals, in source and remote regions are of significant concern for human health and the environment. Therefore it is concluded that HBCD is likely, as a result of its long-range environmental transport, to lead to significant adverse human health and environmental effects, such that global action is warranted." The Committee also decided to establish an ad hoc working group to prepare a risk management evaluation that includes an analysis of possible control measures for hexabromocyclododecane in accordance with Annex F to the Convention for consideration at its next meeting.

1.3. Data sources

17. This risk management evaluation was developed using Annex F information submitted by Parties and observers, including the industry using and producing HBCD.

18. Sixteen Parties and country Observers submitted information (Brazil, Burundi, Canada, China, Colombia, Costa Rica, Czech Republic, Ecuador, Finland, Germany, Japan, Nigeria, Norway, Mauritius, Romania, and Sweden). Five non-governmental Observers submitted information – Bromine Science and Environmental Forum (BSEF), PlasticsEurope/Exiba, Instituto do Meio Ambiente (IMA) Brazil, Extruded Polystyrene Foam Association (XPSA) and Canadian Plastics Industry Association (CPIA) as well as the International POPs Elimination Network (IPEN). All submissions are available on the Convention web site.

1.4. Status of the chemical under international conventions

19. HBCD is included as part of the brominated flame retardants group in the List of Substances for Priority Action of The Convention for the Protection of the Marine Environment of the North-East Atlantic (the OSPAR Convention). The OSPAR Convention is made up of representatives of the Governments of 15 Contracting Parties and the European Commission. Also the Helsinki Commission (HELCOM) has included HBCD in the list of priority hazardous substances.

20. In December 2009, HBCD was considered by the Executive Body of the UNECE Convention on Long-Range Trans-boundary Air Pollution (LRTAP) based on a technical review (ECE/EB.AIR/WG.5/2009/7) to meet the criteria for POPs as defined under the POPs protocol. In 2010 the possible management options for HBCD were assessed to give a basis for later negotiations. The negotiations are expected to be initiated in December 2011.

1.5. Any national or regional control actions taken

21. HBCD has been identified by the EU as a Substance of Very High Concern (SVHC), meeting the criteria of a PBT (persistent, bioaccumulative and toxic) substance pursuant to Article 57(d) in the REACH regulation (ECHA 2008). In February 2011 HBCD was included in the European Chemicals Agency (ECHA) list of substances subject to authorisation under REACH. Taking effect in 2015, HBCD can no longer be used without authorisation. To ensure smooth transition once an alternative is available, the polystyrene industry will have to consider applying for REACH authorization for the use of HBCD in polystyrene to be able to continue HBCD use in Europe after August, 2015. A proposal on classification and labelling of HBCD as a possible reproductive toxic substance was made within the EU (Proposal for Harmonised Classification and Labelling, Based on the CLP Regulation (EC) No 1272/2008, Annex VI, Part 2 Substance Name: Hexabromocyclododecane Version 2, Sep. 2009)

(KEMI 2009). The EU risk assessment committee (RAC) is of the opinion that HBCD should be classified as suspected to damage fertility or the unborn child (Repr.2 H361), and may cause harm to breast-fed children (Lact. H362) (RAC 2010). In the EU HBCD is classified as an environmentally hazardous substance N:R50/53 "Very toxic to aquatic organisms, may cause long-term adverse effects in the aquatic environment".

22. The EU's Directive on Waste Electrical and Electronic Equipment (WEEE) (2002/96/EC) requires the removal of plastics containing brominated flame retardants and of printed circuit boards from electrical and electronic equipment prior to recovery and recycling.

23. The EU Construction Products Directive (Council Directive 89/106/EEC) specifies hygiene, health and environment as one area to be specified in harmonized product standards, together with the other requirements; strength and stability, safety in the event of fire, safety in use, protection against noise, and energy economy and heat retention, as set out in Annex 1 to the Directive. This essential requirement recognizes national regulations for dangerous substances, which could be emitted or released from construction products into indoor air, soil, surface or ground water or which may have an environmental impact. The directive applies to product properties when installed in a building, i.e. not to the manufacturing or demolition or disposal phases. HBCD appears on the indicative list of regulated dangerous substances that should be considered in the product standards (http://ec.europa.eu/enterprise/sectors/construction/documents/legislation/cpd/index_en.htm).

24. In Ukraine, HBCD is registered in the State Register of Dangerous Factors of the Ministry of Health Protection which contains the list of chemicals being used in the industry within the territory of Ukraine. The actual HBCD registration is valid until 2014. The State Committee for Hygienic Regulation is responsible to administrate national measures on chemicals risk assessment and the corresponding hygienic regulation.

25. In Japan HBCD has been designated as a Monitoring Chemical Substance because of its persistence and high bio-accumulation under the Act on the Evaluation of Chemical Substances and Regulation of Their Manufacture, etc. (commonly referred to as the Chemical Substances Control Law "CSCL"). In September 2010, Japanese Ministers of Health, Labour and Welfare, and of Economy, Trade and Industry and of the Environment instructed persons operating the business of manufacturing or importing HBCD to conduct an Avian Reproduction Test (OECD Test Guideline 206) and to report the results thereof by the end of March 2012 under CSCL.

26. In the USA, the EPA anticipates proposing a significant new use rule (SNUR) under section 5(a)(2) of the Toxic Substances Control Act (TSCA) for the use of HBCD in consumer textiles. The rule under development is anticipated to exclude textiles used in motor vehicles, which is an ongoing consumer use in the USA. It would also require persons to notify EPA 90 days before manufacturing, importing, or processing HBCD for use in certain consumer textiles, allowing EPA to evaluate the intended use and, if necessary, to prohibit or limit that activity before it occurs.

27. A proposal for a national ban of HBCD is currently under consideration by the Norwegian Ministry of the Environment (Norway 2011).

28. Canada is currently undertaking a risk assessment of HBCD and will be considering control measures when that assessment has been completed, which is expected in 2011.

2. Summary information relevant to the risk management evaluation

29. Release of HBCD into the environment may occur during production and manufacturing, processing, transportation, use, handling, storage or containment, and from disposal of the substance or products containing the substance. Releases can be from point source discharges or diffuse releases from manufactured product usage. Also, by-product polybrominated dioxins and furans can be released from fires, combustion and incineration of the substance or products containing the substance. Releases are dependent on the conditions of burning, and are small in state-of-the art incinerators, which are, however, not available everywhere.

30. The EU risk assessment (EC 2008) estimates the known environmental emissions of HBCD during production and use to be small, at 0.1 % of the produced and imported volume of HBCD in the EU (8.7 tonnes out of a total volume of 8-9000 tonne), compared to the releases from products and waste. There are, however, concerns for some environmental compartments from this emission. According to the EU RA, 99.9 % of the produced/imported volume of HBCD ends up in articles, mainly in polystyrene (XPS, EPS) used in the construction and building sector where a very long service-life is assumed for these articles. The likely future emissions from these constructions (e.g. at repair or demolition of old buildings, roads, railway and other constructions) have not been assessed.

The risk assessment report acknowledges that future emissions are very likely but that there is no methodology for assessing future emissions. This report also concludes that it is possible that emissions at the end of the service life will be higher than for the production/formulation steps unless virtually all the used polystyrene construction material is recycled and, therefore, the long-term risks associated with the use of HBCD in articles with a long-service life could be severely underestimated in the RA.

31. There are releases of HBCD from products (EC 2008, Miyake et al. 2009, and Kajiwara et al. 2009), but the estimates concerning releases during consumer use of products are highly uncertain (ECHA 2009). 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 (EC 2008). HBCD emissions to indoor air from disturbance of products made from EPS or XPS during service life are estimated to be very low (ECHA 2009), but the installation of boards in buildings represents larger releases of diffuse emissions (SWEREA 2010, KLIF 2011a, ECHA 2008). Several studies show the occurrence of HBCD in indoor air and house dust (Abdallah et al. 2008a and b, Abdallah 2009, Goosey et al. 2008, Stapleton et al. 2008, Stuart et al. 2008, Takigami et al. 2009 a and b) and cabin dust in new and old cars (Harrad and Abdallah 2011). According to the submission from Japan (2011), HBCD fabrics are not used in new car models.

32. Results from a substance flow analysis performed in Japan (Managaki et al. 2009), indicate that emissions from construction materials will continue for several decades and be potentially long-term sources of HBCD leaching or volatilizing to the environment, as well as representing larger releases when buildings are demolished or renovated in the future. Additionally, the increasing HBCD stock seen in the study indicates possible problems arising in the recycling of construction materials in the future, when buildings of the present period are renovated or destroyed. This is also supported by the results from the substance flow analysis in Switzerland (Morf et al. 2008). The Swiss study also highlighted the stock in waste management and landfills as long-term sources of HBCD releases. The significance of those sources depends however on the waste management strategies chosen in the country, if the wastes are incinerated, or disposed of to an uncontrolled or controlled landfill.

33. Releases from waste disposal depend on the disposal method. At the end of their service life, products containing HBCD are likely to be disposed of in landfills, incinerated, recycled, or remain as waste in the environment (UNEP/POPS/POPRC.6/13/Add.2). It is not known to what extent end-products containing HBCD are landfilled, incinerated, left in the environment or recycled. Waste ending up in the municipal waste streams is likely to be put in landfills or incinerated (EC 2008). Solid waste containing HBCD may be scrap materials generated during processing operations, particulates released through aging and wear of end products, and disposal of products at the end of their service life. Products and materials in landfill sites will be subject to weathering, releasing HBCD particulates primarily to soil, and, to a lesser extent, to water and air (ECHA 2009, Environment Canada 2010b). There is also a possibility of formation of other by-products in incineration processes (see below).

34. Insulation boards form the majority of HBCD containing waste. The life span of polystyrene foam in buildings is reported to be 30-50 years (ECHA 2009, Plastics Europe 2009, SWEREA 2010). It is understood that most of this material will go to landfill or incineration, although there will also be some releases of HBCD in dust when buildings with flame retarded insulation boards are demolished. The use of HBCD in insulation boards and the HBCD built into buildings and constructions is increasing and it is likely that releases from EPS/XPS from waste materials will be more significant in the future; particularly from about 2025 onwards, as increasing number of buildings containing HBCD will be refurbished or demolished. This turn-over will be different in different regions of the world, and range from 10-50 years. The EPS industry holds a market share of 35% of the total insulation market for construction in Europe (www.eumeps.org).

2.1. Identification of possible control measures

35. The objective of the Stockholm Convention (Article 1) is to protect human health and the environment from persistent organic pollutants. This may be achieved by listing HBCD in the Convention, possibly accompanied by conditions for certain uses of HBCD. When assessing the control measures, consideration should be given to the releases from production and use of HBCD and from articles containing HBCD, but also to the potential releases from the waste management of HBCD containing articles at the end-of-life stage.

36. HBCD phase-out could include flame retardant substitution, resin/material substitution and product redesign (LCSP 2006). In addition, re-evaluating fire-safety requirements e.g. in applications where fire hazard is absent (such as underground applications, although there may also be risk of fire

during construction and storage of materials prior to construction) or otherwise eliminated would reduce the need for flame-retarded insulation materials. Emissions of HBCD can be reduced in processes where HBCD or articles containing HBCD are used, and during the waste management phase.

37. In the Annex F process, a number of HBCD uses have been identified by Parties and Observers. For high impact polystyrene (HIPS) and production of flame retarded textile back-coatings, alternatives are already available and used in many countries. Alternative chemical flame retardants to HBCD in production of flame retarded expanded polystyrene are being used in some regions, but they are not suitable for all production processes (see section 2.3.1). However, alternative insulation materials as well as alternative construction methods are widely available. These uses and the potential substitutes will be further described in section 2.3.

38. Emission reduction measures and use of best available technology (BAT) and best environmental practices (BEP) could be required in the production and manufacture processes if specific exemptions or acceptable purposes were listed, in order to reduce HBCD releases to the environment. European HBCD and polystyrene manufacturers have in 2006 initiated emission reduction programmes, which are targeted at eliminating emissions from first line users of HBCD (Self-Enforced Control of Use to Reduce Emissions (SECURE) and Voluntary Emissions Control Action Programme (VECAP)). Most of the European PS foam industry implements those risk reduction measures (EBFRIP 2009a) and according to the VECAP progress report 2010, 95% of packaging waste is handled with the best available disposal technique (VECAP 2011). Implementing best practices in handling reduced the total potential releases from 2,017 kg/year in 2008 to 309 kg/year in 2009, and 560 kg/year in 2010 in the survey of member companies (increase in 2010 is explained by a change in the survey and assumptions on potential emissions due to finding that not all users operated with a ventilation system). Also the Japanese curtain and blind industry has developed a coagulation-sedimentation method in the dyeing process to reduce HBCD emissions to water (Japan 2011).

39. If listed in the Convention, waste management measures in accordance with Article 6(1)(d)(ii) should be introduced to ensure that HBCD containing products (EPS, XPS, HIPS, textiles) are disposed of in such a way that their POPs content is destroyed or otherwise disposed of in an environmentally sound manner. This would require identifying HBCD containing materials, e.g. when buildings are renovated or dismantled, to facilitate destruction of the POP content in the waste and to prevent other inappropriate management practices leading to recycling of the POP content.

2.2. Efficacy and efficiency of possible control measures in meeting risk reduction goals

40. Listing HBCD in the Convention would effectively reduce the releases of HBCD. This would require either introducing alternative building techniques or insulation materials to achieve fire safety in construction, or the industry phasing in an alternative to HBCD. For textile and HIPS applications alternatives are on the market already, although HBCD use continues especially in textile applications.

41. According to UNEP/POPS/POPRC.6/13/Add.2 releases occur during the whole life cycle of HBCD containing products. Estimates made in the EU indicate that the releases of HBCD to the environment from production and manufacture are relatively small. According to ECHA 2008a, the estimated total releases of HBCD from manufacture and use of insulation boards (95% consumption of HBCD) and manufacture and use of textiles (2% consumption) were in the same magnitude. Diffuse releases from installation and demolition of PS foams and packaging waste also contribute to the environmental releases of HBCD. In the waste phase especially the releases from PS foam and recycling of electronic and electrical products in developing countries are of importance.

42. Emission control and waste management techniques at the production sites alone will not be sufficient to solve the problem HBCD is posing to the environment and to health, since the diffuse emissions and releases to the water reserves and sewage systems from the use and machining of products containing HBCD, as well as releases when becoming waste also are of significant concern. Several studies have demonstrated the presence of HBCD in household, office and vehicle dust (Abdallah et al. 2008a and b; Abdallah 2009; Goosey et al. 2008; Stapleton et al. 2008; Stuart et al. 2008; Takigami et al. 2009 a and b).

43. Recycled products containing HBCD, including EPS and XPS boards, are potential sources of emissions in the same way as virgin products. According to the Swiss substance-flow analysis, the proportion of HBCD recycled is higher than for material containing other brominated flame retardants, and the recycling percentage of HBCD used in EPS insulation was expected to rise from 30% in 2005 to 60% in 2010 in Switzerland (Geopartner 2007).

44. EPS is commonly recycled if it is recovered without contamination from other materials. Recycling operations for recovery of metals or plastics in electronic products and vehicles are potential sources as well. The EU's Directive on Waste Electrical and Electronic Equipment (WEEE) (2002/96/EC) requires the removal of plastics containing brominated flame retardants and of printed circuit boards from electrical and electronic equipment prior to recovery and recycling. This, however, addresses only a small part of HBCD containing waste. The amount recycled varies between countries but can be significant (EU27 estimate (ECHA 2009) 30% of EPS). EPS recycling options are in place today in Europe and EPS recycle is being undertaken economically. The waste can be ground and mixed with fresh EPS to make new foamed products, or melted and extruded to make compact polystyrene. This can be used to manufacture items such as plant pots, coat hangers and wood substitutes or medium toughened polystyrene and for products from which sheet or thermoformed articles such as trays can be made. As part of a mixed plastic waste, EPS can be recycled to make, for example, fence posts and road signs (EUMEPS 2011). However, in these processes, HBCD will likely be spread into articles that will be difficult to identify, as previously determined by the POPRC for recycling products containing pentaBDE and octaBDE. Fragmented EPS can also be remelted and reused for drainage and soil treatment. Granulated EPS waste is also used to improve the texture of agricultural and horticultural soil (UNEP/POPS/POPRC.6/10; Vogdt 2009).

45. In controlled waste streams materials containing HBCD could be sorted out, but this will not always be technically feasible as HBCD containing materials can not be identified without technical equipment or they are mixed with other materials. EPS as an insulation material has an estimated service life of approximately 30-50 years and collecting and recycling used EPS may be hindered due to difficulties in separating EPS containing HBCD from other materials. In the EU in 2007, the proportion of EPS with flame retardant was 60% of the total EPS demand, and the share of XPS with flame retardant was 92% of the total XPS demand (PlasticsEurope/Exiba 2011). Use of labelling of products or parts of products could be a valuable help in the process of identifying and separating HBCD-containing elements at the end of their life (KEMI 2006). The quantities involved may also be high, especially with regards to insulation foams which have been used since the 1980's.

46. Currently, the most important sources, in relation to the discharge of HBCD to waste in the EU, are the HBCD flame retardant textiles and HIPS (EC 2011). In developing countries, electrical and electronic appliances containing HBCD and other toxic substances are often recycled under conditions which results in a relatively high release of HBCD to the environment and contamination of the sites (Zhang et al. 2009), and exposure of workers (Tue et al. 2010). Open burning and dump sites are common destinations for HBCD-containing articles and electronic wastes (Malarvannan et al. 2009; Polder et al 2008).

47. Controlled incineration is one way to dispose of waste containing HBCD (ECHA 2009, PlasticsEurope/Exiba 2011). The flame retardant decomposes in the incineration plant process. In one co-combustion study in a high temperature pilot facility (>900°C), the foam addition led to a substantial increase in the bromine content of the feedstock in the incinerator (up to six times), but did not affect significantly the overall hazard of the raw gas or emissions from the incinerator. The additional bromine load was, however, almost totally released into the raw gas while the levels in bottom ash remained constant (APME). Experimental evidence confirms that under some conditions incineration of HBCD and products containing HBCD may lead to formation of polybrominated dibenzo-p-dioxins (PBDD) and polybrominated dibenzofurans (PBDF) including in state of the art municipal solid waste incineration facilities (APME; NCM 2004). Formation of mixed brominated and chlorinated dioxins and furans occurs primarily via de novo synthesis, similar to PCDD/F formation (Shuler and Jager 2004). However, in state-of-the art incinerators PBDDs and PBDFs formed from waste containing HBCD will likely be destroyed at the very high operating temperatures, and emissions to the environment will be controlled via the flue gas treatment systems. The incineration efficiency and the operating conditions of the flue gas treatment systems are of great importance to the resulting emissions of dioxins (NCM 2004) and BFRs (including HBCD) can be destroyed under controlled combustion conditions with high efficiency (Weber & Kuch 2003). However, there is potential for the release of brominated by-products from uncontrolled burning and accidental fires, pyrolysis/gasification plants, and from incinerators that are not functioning well (Weber and Kuch 2003, ECHA 2009). Desmet et al. (2005) also documented the formation of bromophenols, known precursors potentially forming PBDDs and PBDFs, during combustion of flame-retarded extruded polystyrene containing HBCD. The study did not investigate the formation of brominated dioxins and furans but noted that it was highly probable that various brominated dioxin isomers would be formed from bromophenols, although they were not measured.

48. State of the art incineration is expected to be more widely available in some countries in the coming years, hence diverting HBCD containing materials from landfill. However, currently in many countries landfilling is the most common way of waste disposal, leading to HBCD containing waste

accumulating in the landfills. In Japan, waste products containing HBCD (for example EPS/XPS, and ASR⁵) are utilized as a resource by material recyclers and thermal recyclers at the disposal phase, in order to promote sustainable development.

Flame retardancy requirements

49. Polystyrene and its copolymers have a tendency to depolymerise at fire temperatures, resulting in release of volatile products with high fuel value hydrocarbons. Fire performance of a material is also affected by fillers, coatings, laminates, pigments, dyes, and other compounding agents. Flammability of polymers is mainly assessed through ignitability, ease of extinguishment, rate of flame spread, rate of heat release, and smoke formation which are inherent features of materials response to fire (Weil & Levchik 2009). Consequently, inherently flammable materials may need to be treated with a flame retardant to meet such fire performance criteria, required in countries' regulations for a specific use. In national legislation, the requirements are normally specified in general and relative terms, and they do not require the use of specific flame retardants. To demonstrate that the requirements are met, there are prescribed verifiable criteria, which standardisation bodies such as ISO, CEN and UL often have helped to develop (KEMI 2006).

50. The European fire classification system for construction products and materials does not set requirements on individual materials in a building product, but on the fire performance of the complete product in its intended mode of use. It is, however, common to have specific national regulations for the fire performance of uncovered insulation materials, which does not necessarily predict behaviour of the material in a real fire situation.

51. Consequently, depending on the application of the material and also the use conditions (for instance the number of floors in the building), the required flame retardancy varies from country to country within the EU. Building element performance based criteria play a central role in the new EU Construction Product Directive (CPD). It has also been suggested that the "performance based" approach would result in improved fire safety at lower cost (EUMEPS 2011).

52. Many countries have set standards for either building materials with regards to their contribution to fire or fire performance criteria for building elements like the floor, wall, or ceiling (SWEREA 2010; KLIF 2011a; KLIF 2011b). Fire safety regulations require that flame retardant must be used in Austria, Canada, China, Czech Republic, Denmark, Germany, Hungary, Iceland, Netherlands, Slovakia, Slovenia, and Switzerland in all building applications, irrespective of the use (Germany, PlasticEurope/Exiba 2011). Moreover, flame retardants are used in EPS stored in warehouses with the intent of delaying ignition and slowing subsequent fire growth. In Italy, Portugal and UK flame retarded PS foams are generally used (BSEF 2011). In the UK there are no formal regulations that would exclude the use of non-flame retarded EPS/XPS, however, according to the UK plastic industry, almost the entire market share of EPS/XPS in the UK is flame retarded due to requirements from the insurance sector. Other non-combustible alternative materials, such as stone and glass wool, are used for some applications, where high fire safety requirements have to be met. Flame-retarded PS foam may be used in some building applications in Finland, Norway, and Sweden, although it is not required. Sweden and Norway, with a performance approach to the final product in their regulations, use much less brominated flame retardants than countries with more specific fire requirements on a material level (KLIF 2011a). In Sweden and Norway, the industry has voluntarily withdrawn HBCD containing products from the market, which is possible because alternative construction techniques can be used, even with EPS applications.

53. In the USA and Canada there are numerous regulations and standards that apply to insulation used in the building industry. These regulations and standards may exist at the national, state, county, or municipal level (LSCP 2006). The most common requirement in various building codes for building materials is the Tunnel Test ASTM E 84 (Weil and Levchik 2009). With UL-94, plastics can be divided into five fire rating classes.

54. In Australia there are very low formal requirements concerning fire performance of materials which would not necessarily require the use of flame retarded EPS/XPS. It seems, however, that if EPS/XPS is used instead of other materials it is flame retarded voluntarily (KLIF 2011b).

55. The requirements for flame retarded HIPS depend on the application. Use in the manufacture of television sets is probably the largest application for HIPS, which in the US requires UL-94 V-0 rating, which is more stringent than the European requirement. To pass UL-94 V-0 requirements, approximately 10 % w/w flame retardant in combination with antimony oxide is required. HIPS is

5 ASR: 'automobile shredder residue' - denoting the matter left over after the recovery of metals and other reusable materials from dismantled and shredded vehicle bodies.

usually processed at 220-230°C. Ordinary grade HBCD is not stable enough at these temperatures, and thermally more stable bromine compounds are favoured. There are, however, stabilized versions of HBCD on the market for higher temperature uses (Weil and Levchik 2009).

56. The demand for textile flame retardancy is mainly in work clothing, institutional upholstery, institutional and commercial carpet, transportation, military garments, and bedding. Upholstered furniture flammability regulations are in place in the UK (standard BS 5852) and the State of California (USA). A Federal open-flame test requirement is in effect for mattresses manufactured or imported on or after July 1, 2007 in the US. It is not known if HBCD is used for this application, as there are many alternative methods to pass this requirement, including use of barriers under ticking (Weil and Levchik 2009).

57. Fire safety regulations have been discussed in more detail in KLIF (2011a and b).

2.3. Information on alternatives (products and processes)

58. The POPRC has concluded that HBCD is likely, as a result of its long-range environmental transport, to lead to significant adverse human health and environmental effects, such that global action is warranted (UNEP/POPS/POPRC.6/13/Add.2). To reduce the risks to human health and the environment the use of HBCD for different applications must be minimized. The target or aim of any risk reduction strategy for HBCD should be to reduce and eliminate emissions and releases taking into consideration the indicative list in Annex F including technical feasibility of possible control measures and alternatives, the risk and benefits of the substances and their continued production and use. In considering any strategy for a reduction in such risks, it is important to consider the availability of substitutes in the sectors of concern. In this regard, the replacement of HBCD by another chemical or non-chemical alternative needs to take account of factors such as:

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

59. Based on the submissions from Parties and Observers, there is currently a need for insulation to meet energy efficiency requirements, and specifically flame retarded insulation materials due to specific fire safety requirements in some countries. However, the safety requirements do not identify any specific flame retardant substances or groups of flame retardant substances that have to be used, and the choice has to be done by the manufacturer.

60. Technically feasible alternatives are commercially available for most of the applications in which HBCD is used. Chemical drop-in alternatives for one-step EPS and XPS production are becoming available in short term. Alternatives include flame retardant substitution, resin/material substitution and product redesign. Several of these alternatives are halogen-free and have been considered to be better alternatives for the environment and health in the following evaluations: ECHA 2009; SWEREA 2010; and KLIF 2010 (Table 3). However, they may present other risks, such as other harmful substances or dust, that need to be taken into account (LCSP 2006, KLIF 2011c).

61. When considering chemical alternatives a distinction should also be made between additive flame-retardants and those chemicals that are covalently bound and less subject to release to the environment. Moreover, the inherent flammability of the resins/ materials should be taken into account and where possible non-combustible insulation materials should be considered as should alternative building techniques.

62. A discussion of different strategies and the availability and suitability of alternatives to HBCD is provided below along with an overview of technically feasible and commercially available alternatives (Table 3). Some of the alternatives, for example decaBDE, are not permitted in all countries. Additional information is also available in DEPA (2010), SWEREA (2010), KLIF (2011a) and KLIF (2011b).

Table 3. Summary table of technically feasible and commercially available alternatives to the use of HBCD (based on SWEREA 2010 and Annex F submissions).

Material	Applications	Chemical alternatives	Alternative materials and product redesign techniques
EPS & XPS	Insulation of foundation, walls and ceilings. Ground deck, parking deck etc.	No 'drop in' replacement chemicals commercially available at present for all production processes and regions For two step EPS production process, in which HBCD can not be used, another flame retardant is used.	EPS and XPS without FRs, using thermal barriers. Polyisocyanurate foams, including modified urethane foams. Phenolic foams. Blankets (fiber batts or rolls) that may contain rock wool, fiber glass, cellulose or polyurethane foam. Cellular glass, foam glass Polyester batts. Loose fills that may contain rock wool, fiber glass, cellulose or polyurethane foam. Reflective insulation systems.
HIPS	Housings of electronic products. Wiring parts.	deca-BDE, Tris(tribromoneopentyl) phosphate/ATO TBBPA-DBPE /ATO, 2,4,6-Tris(2,4,6-tribromophen oxy)-1,3,5 triazine/ATO, Ethane-1,2-bis(pentabromophenyl)/ATO, Ethylenebis(tetrabromophtalimide)/ATO	Alloys of PPE/HIPS or PC/ABS treated with phosphorus containing flame retardants
Textile back coatings	Protective clothing. Carpets. Curtains. Upholstered fabrics. Tents. Interiors in public transportation conveyances (e.g., automobiles, trains, aircraft, etc.). Other technical textiles.	deca-BDE, decabromodiphenyl ethane, ethylene bis(tetrabromophtalimide), chlorinated paraffins, ammonium polyphosphates	Inherently non-flammable materials: wool. Inherently flame retardant fibers: rayon, polyester fibers, aramids and other synthetic fabrics. Other textiles with ammonium polyphosphates (APP). Textiles with intumescent systems.

2.3.1 Flame retarded expanded and extruded polystyrene (EPS/XPS)

63. The biggest application for HBCD use is polystyrene insulation foam production. HBCD use in EPS/XPS could be phased out by using an alternative flame retardant, using alternative insulation materials or alternative building techniques that achieve the same level of fire safety without a flame retardant.

64. The first consideration would be to avoid the use of HBCD and other flame retardants in cases where no fire hazard exists. These uses include placement of insulation between two non-combustible wall surfaces such as stone or concrete and uses where insulation is placed between building foundations and soil. These design changes could be implemented by the end-product manufacturer (LCSP 2006; KLIF 2011c), and be marketed subject to building code requirements. In addition, flame retardant EPS/XPS may be used e.g. in other underground applications, such as ground frost protection or road/railway/bridge construction on poor load-bearing subsoil. Today, such use takes place in the EU, Scandinavia, USA, Canada, Japan, Thailand and Jamaica (EC 2011; EPS 2011). In Norway, the

use of flame-retarded EPS geof foam was discontinued in 2004 and since then there have been no accidental EPS fires (Aabye and Frydenlund 2011). At the construction site the fire-safety is secured by surveillance, fences and careful use of cutting and welding equipment etc.

Drop-in chemical alternatives to HBCD in EPS/XPS applications

65. According to the Annex F submissions there were no commercially or technically viable drop-in chemical alternatives to HBCD as a flame retardant in XPS production and the most common 'one-step' EPS manufacturing process, which is used at least in Europe and generally in North America currently. In March, 2011, an alternative for HBCD in EPS/XPS (Emerald 3000) was announced. In the 'one-step' production process all additives are mixed in the styrene solution prior to polymerisation. In the alternative 'two-step' process the beads are polymerized in the first step without the flame retardant additive and pentane; the possible flame retardant and pentane are added in the second step. In the 'two-step' process, the flame retardant must be able to penetrate into the ready-made bead. HBCD penetrates the beads poorly after polymerization, and therefore other flame retardants must be used.

66. All European and also most North American polystyrene manufacturers use a 'one-step' process, in which no alternative to HBCD that would meet the technical (foam properties, environmental profile) and performance criteria (i.e. delaying ignition and slowing subsequent growth in testing) is currently on the market. According to the HBCD industry, pure styrenic polymers like HIPS, EPS and XPS require brominated flame retardants to reach the desired fire safety standards. The polystyrene industry is in the process of finding alternatives to HBCD jointly with flame-retardant producers. Also US EPA is discussing with the industry new alternatives to HBCD in polystyrene foams, but the conclusions are not yet publicly available.

67. As stated above, in March, 2011, Great Lakes Solutions announced it will scale up production of a high molecular weight brominated co-polymer of styrene and butadiene flame retardant (Emerald™ 3000) suitable for EPS and XPS, developed by Dow Chemicals (DOW 2011). It is expected, however, to take several years for the industry to fully convert to this technology. According to the industry hazard assessment, it is persistent, but not bioaccumulative or toxic. The USEPA Design for Environment program will conduct a hazard assessment of HBCD alternatives used in XPS/EPS.

68. Two production facilities in North America, and possibly others outside Europe, utilise a "two-step" process. It is unclear what is currently used in the "non-HBCD EPS" process, but at least in the past tetrabromocyclooctane and dibromoethyldibromo-cyclohexane were used (LSCP 2006). There are also concerns about the environmental or health properties of these substances.

69. The Japanese EPS industry is aiming at replacing HBCD in its production processes by the end of 2012 and also the industry producing XPS is working towards reduction in HBCD use by reconsidering HBCD content but also the need for HBCD in the product (Japan 2011).

Alternatives to use of flame retardant EPS/XPS

70. Flame retarded EPS and XPS foam used for building insulation can also be replaced by alternative insulation materials which according to KLIF (2011b) can fulfil the same insulation and fire safety requirements and be as moisture resistant, and equally rigid or more flexible than flame retardant EPS/XPS. This has been reported as a more complex approach than simple flame retardant substitution because it has a greater effect on overall product cost and performance (LCSP 2006).

71. The properties of EPS make it especially suitable for insulation of exterior walls, flat roofs, floors and sandwich elements. Technically feasible alternatives for the key uses of flame retarded EPS are commercially available in common insulation materials used worldwide. Alternative materials include polyisocyanurate foams, phenolic foams, blanket insulation, fiberglass, cellular glass, polyester batts, sheep wool and reflective insulation systems including foils, films, or papers (SWEREA 2010), and also encompass insulation products such as polyurethane foams and loose-fill insulation that can be poured in place, spray-applied or blown into the building structure during construction. Flame retardants (such as boric acid) with questionable environmental or health profile may, however, also be used in these materials. Loose-fill insulation consists of small particles of fiber, foam, or other materials (US DOE 2010). These small particles form an insulation material that can conform to any space without disturbing any structures or finishes. This ability to conform makes loose-fill insulation well suited for retrofits and for places where it's difficult to install other types of insulation. The most common types of materials used for loose-fill insulation include cellulose, fiberglass, and mineral (rock or slag) wool. All of these materials are produced using recycled waste materials. Cellulose is primarily made from recycled newsprint. Most fiberglass contains 20%–30% recycled glass. Mineral wool is usually produced from 75% post-industrial recycled content. Loose-fill

insulation can also be produced from materials such as vermiculite or perlite. Cellular glass, perlite and wood fibre insulation boards are considered to be as technically feasible as EPS for all the key uses except for sandwich panels. The different materials available on the market all have different thermal insulation properties, areas of use and require their own installation methods (US DOE 2010, KLIF 2011b). They also vary with regards to fire-safety properties, but there are alternatives that are able to meet the same fire-safety requirements, or higher, as the flame retarded EPS (KLIF 2011b, 2011c).

(a) Polyisocyanurate foams include modified urethane foams that utilize chemical flame retardants such as tris monochloropropyl phosphate (TMCPP, TCPP) and tris chloroethyl phosphate (TCEP). An EU Risk Assessment (ECB 2008) is available for TCMPP, identifying risk only for worker exposure. In the TCEP manufacturing process ethylene oxide (a carcinogen) is used, and TCEP appears to be a reproductive toxicant, is found in the Arctic indicating long-range transport, and is considered a carcinogen by the California Office of Environmental Health Hazard Assessment. According to LCSP (2006) due to the chlorinated and brominated flame retardants used in the manufacture of polyisocyanurate insulation products, these cannot be considered to be preferable alternatives because of their health effects.

(b) Phenolic foams are in use in roofing, cavity board, external wall board, and floor insulation. They are mostly used to bind glass fiber to make insulation products. One concern over their use is that formaldehyde, a human carcinogen, may be used for making phenolic resins monomer. Formaldehyde is listed by the International Agency for Research on Cancer (IARC) as a known human carcinogen (LCSP 2006). This has to be considered at the production sites, using available emission control techniques and safety restrictions protecting the workers. According to KLIF (2011c) phenolic resin monomers may, however, be produced also without formaldehyde as other alternatives are available.

(c) Blanket insulation is as much a technical alternative as an alternative material. It is usually made of fiber glass or rock wool and can be fitted between studs, joists, and beams. It is available in widths suited to standard spacings between wall studs or floor joists. Continuous rolls can be hand cut and trimmed to fit various spaces. The blankets are available with or without vapour retardant facings. Batts with special flame resistant facing are available where the insulation will be left exposed.

(d) Cellular glass and foam glass can be used in some EPS/XPS insulation applications, such as warm roofing systems, parking decks, roof decks, ventilated facades, indoor insulation, floor insulation in industrial environments, and ground and perimeter insulation. They have a closed cell structure and are made of recycled glass without binders. They are available in different densities for different loadings and do not contribute to fire. They are also impervious to water.

(e) Fiberglass is a synthetic vitreous fiber. Loose-fill insulation is typically blown into place or spray-applied by special equipment. It can be used to fill existing wall cavities and for irregularly shaped areas.

(f) Reflective insulation systems include foils, films, or papers that are fitted between studs, joists, and beams and commonly used to prevent downward heat flow in roof applications. Common materials include foil-faced paper, foil-faced polyethylene bubbles, foil-faced plastic film, and foil-faced cardboard.

(g) Other commonly used insulation materials include polyester batts and sheep wool which can be fitted between studs, joists, and beams.

72. Fiberglass, glass wool, and mineral wool are considered synthetic vitreous fibers. They also may have occupational health effects. When these fibers are suspended in air they can cause irritation of the eyes, nose, throat, and parts of the lung. Animal studies show that repeatedly breathing air containing synthetic vitreous fibers can lead to inflammation and fibrosis of the lung. (ATSDR 2004). Protective clothing and equipment (face masks, goggles, gloves etc.) are available and used by construction workers to avoid irritations from contact and breathing in the fibres. This will only be of importance in the working environment, since the fibrous material is built inside the wall, foundation and ceilings in the buildings and constructions, and during demolition and refurbishment. In addition fiberglass may be bound into batts using adhesive binders, which can contain phenol formaldehyde, a hazardous chemical known to slowly off-gas from the insulation over many years.

73. The substitution of HBCD for building and construction purposes may also be aided by product redesign i.e. by technical solutions and changes in building and construction practice. Non-flame retarded EPS boards are used in a number of countries in combination with other construction materials which protect the EPS from catching fire (KLIF 2011a). Examples of product redesign

include using fire barrier material and other strategies to separate and reduce the source of heat from the product. These design changes could be implemented by the end-product manufacturer (LCSP 2006). By using thermal barriers it may be possible to achieve fire safety without the use of flame retarded EPS/XPS. Thermal barriers are fire resistant coverings or coatings that separate the insulation material from the building interior. The insulation material may for example be placed between two non-combustible wall surfaces such as stone or concrete or between building foundations and soil (LCSP 2006; KLIF 2011c). The technique can be used in constructions such as external facades, floor slabs or flat roofs (KLIF 2011c). In roofs a thermal barrier is placed between the EPS and metal roofing. For applications where the insulation is in direct contact with the ground there is no need of flame retarded plastic foams, since the XPS is typically placed between a concrete slab and the ground and the insulation material is well protected from fire exposure (Klif 2011 c). Thermal barrier materials include: gypsum boards, gypsum or cement plasters, perlite boards, spray-applied cellulose, use of mineral fiber or gypsum coatings and selected types of plywood. All these materials are currently in common use in domestic and commercial building construction (LCSP 2006; SWEREA 2010).

74. Thermal barriers are subject to country-specific building code requirements (SWEREA 2010), and are currently used in Finland, Norway, Sweden and Spain where the national fire safety requirements are issued by building codes. By considering also technical aspects and solutions such as the use of thermal barriers and how insulation is implemented in the building construction, the building codes in these countries specify which insulation products may be used and for which type of construction. Hence fire safety may be achieved even when using non-flame retarded EPS/XPS. It is to be noted, however, that the use of thermal barriers may not be feasible in all countries in the short term due to technical standards, and building codes (SWEREA 2010) and policies. In addition, current fire safety regulations in some countries require the use of a flame retardant in EPS/XPS irrespective of their use, for storage and transportation safety.

75. The alternative insulation materials/techniques may have characteristics that are different from XPS and EPS and that are more or less appropriate for some specific use scenarios (such as resistance to water absorption, resistance to mechanical loadings (high compression strength) and structural integrity for service life) (ECHA 2009; US DOE 2010). According to the submissions, alternative insulation materials to EPS/ XPS are available for all uses, with the exception of some demanding XPS use in moist or freeze/thaw sensitive applications in North America (XPSA/CPIA 2011). Use of alternative insulation materials/techniques may also incorporate different environmental issues such as increased energy costs during transportation, and may come with their own unique set of health- and/or environmental risks which in most instances are not too well known. When release to the outer environment is not considered, the health effects of any given insulation material is primarily of importance in the work environment, since the insulation material is built inside the wall, foundation and ceilings. Exposure to alternative insulation materials during building repair, refurbishment and demolition must also be considered. The environmental and health properties of several alternative materials were assessed in a recent Norwegian report which concluded that the alternatives contain chemicals that are less problematic than HBCD as none of them are halogenated or have been classified as PBT or have been identified as POPs (KLIF 2011c). However, for polyurethane rigid foams, the majority of the alternative flame retardant chemicals in use are halogenated substances.

76. Replacing EPS/XPS insulation with other materials can furthermore affect overall product cost and performance, and may additionally require a different approach during building and construction. However, current building practice from Sweden and Norway, where most of the EPS and XPS used is HBCD-free, suggests that fire-safety of building materials and buildings can be obtained at a reasonable cost without the use of HBCD and without altering traditional building and construction techniques to a great extent. According to an analysis on alternatives to flame retardant EPS made in Norway, a change from flame retarded EPS to the alternative insulation materials would consequently not compromise fire safety and the alternatives would in general be able to meet the same requirements, or higher, as the flame retarded EPS. The alternatives, including non-flame retarded EPS in combination with thermal barriers, typically have better fire performance and can compete with regard to the insulation properties and moisture resistance required in most applications in both cold and warm climates (KLIF 2011c). According to KLIF (2011c) the price of the cheapest alternatives ranges from more or less the same price as for flame retarded EPS to approximately 30 % more.

2.3.2 Alternatives to HBCD in high impact polystyrene (HIPS) plastic

77. HBCD is not widely used in HIPS and it is reasonable to assume that alternative flame retardants are available for this application (Table 3). It is mainly used in V-2 grade HIPS where aliphatic BFRs are more efficient than aromatic BFRs. Decabromodiphenyl oxide (ether) i.e. deca-BDE is the most widely used flame retardant for HIPS due to its low cost and high bromine

content (Weil and Levchik 2009). It is also used in electronic wire insulation. It may, however, not be recommended for use as a substitute for HBCD due to concerns about its impact on human health and the environment (EC 2002; US EPA 2010) as well as debromination to compounds such as PentaBDE and OctaBDE (UNEP/POPS/POPRC.6/2). In the EU, the introduction of the RoHS and WEEE Directives phased out the use of deca-BDE in electronics. In the US, the industry is voluntarily withdrawing Deca-BDE from most uses by 2013. In Norway, the manufacture, import, export, sale and use of substances and preparations that contain 0.1 percent by weight or more of deca-BDE was banned in 2004.

78. Other chemicals that can be used as alternatives to HBCD in HIPS include a variety of brominated flame retardants used in conjunction with antimony trioxide (ATO). These include: Tris(tribromoneopentyl)phosphate; Tetrabromobisphenol A-Bis(2,3-dibromopropyl ether) (TBBPA-DBPE); 2,4,6-tris(2,4,6-tribromophenoxy)-1,3,5 triazine; Ethane-1,2-bis(pentabromophenyl) and Ethylenebis(tetrabromophthalimide).

79. Alternative materials to HIPS are also on the market, thus circumventing the problem of finding a chemical substitute to HBCD. More specifically in electrical products HIPS can be replaced by various alternative materials, including blends of polycarbonate / acrylonitrile butadiene styrene (PC/ABS), polystyrene / polyphenylene ether (PS/PPE) and polyphenylene ether / high impact polystyrene (PPE/HIPS⁶) without flame retardants or with the use of non-halogenated phosphorus flame retardants (Brazil 2011, DEPA 2010). Organic aryl phosphorus compounds, resorcinol bis (biphenyl phosphate), bis phenol A bis (biphenyl phosphate), polymeric biphenyl phosphate, diphenyl cresyl phosphate, triphenyl phosphate (Kemi 2006) appear to require a co-additive to prevent migration of the phosphorus compound to the surface of HIPS. The phosphorus alternatives for HIPS are required to be used at higher loadings (ECHA 2009). The co-polymer blends are widely used in electronic equipment with or without flame retardants, have higher impact strength and are inherently more resistant to burning because they form an insulating char foam surface when heated (DEPA 2010).

2.3.3 Alternatives to HBCD use in textile back-coating

80. HBCD is used as a flame retardant in the back coating of textiles for upholstered furniture, upholstery seating in transportation vehicles, draperies, wall coverings, mattress ticking, and interior textiles such as roller blinds (LCSP 2006,; ECHA 2009; SWEREA 2010). The typical concentration of HBCD in textile applications is high compared to other applications, at 6 to 15% in a polymer (CEFIC/EFRA 2006, EC 2008). HBCD is relatively expensive, and hence used mainly where companies find that only HBCD meets the performance needs (ECHA 2008b).

81. Flame retardant use in textiles can be avoided if the material itself is non-flammable or has low flammability. Some natural materials such as wool may therefore be used as barrier materials in furniture (Norway 2011; SWEREA 2010). Other inherently flame retardant materials include rayon with a phosphorus additive, polyester fibers, and aramids (Weil and Levchik 2009). Also several chemicals are available that may be used as drop-in alternatives for HBCD in textile applications. For textile back coating, chemical alternatives to HBCD include deca-BDE, decabromodiphenyl ethane, ethylene bis(tetrabromophthalimide), chlorinated paraffins and ammonium polyphosphates (ECHA 2009; KLIF 2011a). Concerns about deca-BDE are described above. Long chain chlorinated paraffins are reproductive toxicants to humans, show chronic toxicity with effects on liver and kidneys, and are potential carcinogens (ECHA 2009). For different textile sets it is also possible to use ammonium polyphosphate (APP) in the backcoating.

82. In textiles fire safety may also be achieved by the use of intumescent systems (KLIF 2010). Intumescence is the formation of a foamed char, which acts as heat insulation. An intumescent system is generally a combination of a source of carbon to build up char, an acid generating compound and a decomposing compound to generate blowing gases to produce foamed char (Weil & Levchik 2009). This foam attains a thickness of 10 to 100 times that of the originally applied coating and insulates the substrate material through its low thermal conductivity, making intumescent systems efficient at reducing flammability and the exposure of fume gases (KEMI 2006). Several intumescent systems linked to textile applications have been on the market for about 20 years, and have successfully shown their great potential. Intumescent systems include use of expandable graphite impregnated foams, surface treatments and barrier technologies of polymer materials (SWEREA 2010). Intumescent systems may not be applicable to the same sets of textiles as BFR-based backcoatings.

6 PPE/HIPS: alloy of polyphenylene ether and high impact polystyrene

83. According to the submission from Japan, HBCD has been replaced in automotive application fabrics used in new car models. However, the supply of fabrics that contain HBCD will continue for some time as these fabrics continue to be used in repair parts for older models (Japan 2011).

2.4. Summary of information on impacts on society of implementing possible control measures

84. As the persistent, bioaccumulative and toxic properties of HBCD as well as its potential for long-range transboundary transport were shown in the risk profile agreed by the POPRC of the Stockholm Convention, a positive impact on globally sustainable development from an elimination of HBCD is to be expected. If production, use, and waste management of HBCD are not controlled, and were to continue or increase, the levels in the environment including in humans and animals will likely continue to rise, even in locations far from production and use.

2.4.1. Health, including public, environmental and occupational health

85. It is important to maintain the level of fire safety by using alternative flame retardants, materials or building techniques to minimise loss of lives, damage to persons and property and harmful emissions from accidental fires.

86. A positive impact on human health and on the environment can be expected from reduction or elimination control measures on HBCD on a global scale. In humans HBCD is found in blood, plasma, breast milk and adipose tissue. The main sources of exposure presently known are contaminated food and dust. Imposing control measures would likely ensure that the levels of HBCD in agricultural products like farmed (and wild) fish, milk/milk products and various meat products will decrease. In the short-term, the most positive effect would be anticipated to be on the indoor environment; with HBCD levels in dust being completely eliminated or reduced as a consequence of a ban. A positive outcome of this would be reduced exposure to humans via food and dust, particularly to children, who have been shown to ingest more dust than adults. Worker exposure in plants producing flame retarded EPS, and of workers involved in the recycling of electric and electronic appliances in developing countries would be reduced as well (UNEP/POPS/POPRC.6/13/Add.2).

87. Though information on the human toxicity of HBCD is to a great extent lacking, embryos and infants have been identified as vulnerable groups that could be at risk (UNEP/POPS/POPRC.6/13/Add.2, RAC 2010), particularly due to the neuroendocrine and developmental toxicity of HBCD observed in animal studies. Phase-out or elimination of HBCD would also be particularly beneficial to Arctic indigenous peoples who depend on traditional native foods and therefore are at much greater risk of exposure than other communities. The particular risks posed by POPs to Arctic ecosystems and indigenous communities are acknowledged in the preamble to the Stockholm Convention.

88. A phase out of HBCD in articles and waste is essential to reduce the exposure of the environment and wild life, human exposure through contaminated food and water, and the direct exposure to workers from recycling operations, or at the waste disposal sites as well as open burning of HBCD containing waste in developing countries (Malarvannan et al. 2009; Polder et al. 2008; Tue et al. 2010; Zhang et al. 2009).

89. The overall fire safety benefit of regulations requiring flame retardants has been questioned by a group of scientists since it is suggested that they can increase the release of toxic gases and soot which are the cause of most fire deaths and injuries (EHP 2010). Combustion of materials containing HBCD or other halogenated flame retardants during accidental fires and burning flame-retarded waste can increase the toxicity of fire effluents by increasing the release of carbon monoxide, acid gases such as hydrogen bromide, and brominated and chlorinated dioxins and furans (Halogenated Flame Retardants 2010). An overall reduction of flame-retarded materials may therefore lead to a smaller risk of health problems for the general public and fire fighters, if fire safety can be achieved by other means.

2.4.2 Biota (biodiversity)

90. A phase-out of HBCD is essential to avoid an increase of levels in wildlife already at risk. HBCD is considered very toxic to aquatic organisms. There is a risk of adverse effects in marine mammals and fish in the vicinity of point sources and in regions with elevated background levels. The measured concentration levels in biota exceed the PNEC for secondary effects of 5 mg/kg ww in the EU risk assessment of HBCD (EC 2008). Levels in birds from European regions with elevated background levels or near local point sources are concluded to lie near the threshold levels for adverse effects. Further indications for concern come from recent preliminary data obtained with captive

American kestrels which suggest a risk for reproductive and developmental effects also in wild birds in remote regions (UNEP/POPS/POPRC.6/13/Add.2).

2.4.3 Economic aspects, including costs and benefits for producers and consumers and the distribution of costs and benefits

91. Economically feasible alternative materials and techniques exist for many applications where HBCD is used. EPS and XPS without flame retardants can be used in many applications and do not represent a higher cost to the manufacturer. EPS and XPS insulation boards are recommended by the producers to be covered by other materials in buildings and constructions to improve the insulation and thermal properties, as well as fire resistance, even if flame retarded (KLIF 2011c, EUMEPS 2011b). The market in Scandinavia is dominated by polystyrene boards without flame retardants. This is accomplished by fire safety regulations not requiring treatment with a flame retardant, acquiring the same level of protection through other means and relies to a lesser extent on flame retardants (SWEREA 2010).

92. The cost for phase out of HBCD will be low for regions where HBCD is largely phased out or not widely used (e.g. Scandinavia and most developing countries, according to the Annex F submissions and use data). In other regions the impact will depend on whether alternative flame retardants will be available when HBCD is phased out. There will be greater impact in markets with a substantial production and use of HBCD flame retarded EPS insulation boards (especially Europe). As there are currently no alternative chemical fire retardants available for EPS/XPS, HBCD elimination without a phase-out transition period will affect production of flame retarded EPS/XPS in all regions. There are, however, also a large number of alternative materials and product design alternatives for EPS and XPS (Table 3). Conclusively, the cost implications for producers are considered to be low to moderate, and a switch to other flame retardants, alternative materials and design solutions will stimulate some producers (KLIF 2010).

93. The cost of a phase out of HBCD uses should be limited for most developing countries, as the majority of the HBCD use takes place in Europe, the US and China. A ban of HBCD in the absence of a drop-in chemical alternative could have a negative impact on the EPS and XPS industry in Europe and to the workforce in this sector (PlasticsEurope/Exiba 2011). The threats mentioned include styrene supply changes and issues related to small and medium sized enterprises' competitiveness. In the US and Canada, a HBCD ban would cause difficulties for at least one application where flame retarded XPS is the only product recommended and accepted by the building codes (XPSA/CPIA 2011). Drop in chemical substitutes to HBCD in EPS and XPS are likely to soon become commercially available and to be phased in (DOW 2011; BASF 2011).

94. In several countries the use of EPS and XPS without flame retardants instead of flame retarded EPS/XPS would require adjustment of policies and a change in the implementation of fire safety standards. This would take time, but the costs can be considered moderate. In the EU there are already initiatives to harmonize the fire safety regulation standards, and HBCD is on the indicative list of hazardous substances that should be avoided for use for fire protection in buildings and constructions. This would also be an important driver to change the fire regulations (KLIF 2010a).

95. For drop-in chemical substitutes, two main types of costs have to be considered concerning the switch from one flame retardant to another (SWEREA 2010);

The switching cost, which is the cost of reformulation, in other words the cost of the development work or equipment change. Manufacturing and processing facilities may need to invest in new equipment in order to shift to alternative flame retardants. This cost is difficult to estimate, and usually contains the cost of those research and development endeavours which did not succeed in finding an efficient flame retardant alternative. This is a cost which is generated at the beginning of a product life cycle.

The operating cost which reflects the price of the flame retardant (raw) material cost. In addition, daily operation costs may be different for the new process steps required to manufacture other flame retardant chemicals. To ensure economic viability, flame retardants must be easy to process and cost-effective for what high-volume manufacturing conditions are necessary. The costs of manufacturing are heavily dependent on the costs of raw materials, but the degree of this dependency varies among the flame retardants.

96. In absence of updated fire safety standards (e.g. performance based) and techniques that do not require addition of chemical flame retardants, the PS foam industry may require time to adapt to the new flame retardant alternatives. A time limited exemption for use of HBCD in polystyrene foam would therefore reduce the economic impact. Nevertheless, pressure from consumers and national

legislations are already forcing the industry to change to less hazardous flame retardants (SWEREA 2010).

97. In accordance with Article 6(1)(d)(ii), HBCD containing products (EPS, XPS, HIPS, textiles) should be disposed of in such a way that their POPs content is destroyed or irreversibly transformed so that they do not exhibit the characteristics of POPs or otherwise disposed of in an environmentally sound manner. Specialized waste management and disposal related to HBCD (buildings and articles) could be costly for developed countries dominating the consumption of HBCD globally. The amount of waste that needs to be managed depends on the time it takes to phase out HBCD. In the EU it has been estimated that about 170,000 tonnes of HBCD have been consumed between 1988 to 2010, which by 2017 (taking into account all applications used) is estimated to total about 23 million tonnes of HBCD containing waste⁷. Out of this, less than one million tonnes of waste have been disposed of by 2010 and it is expected that in 2050 more than 5,000 tonnes of HBCD will have to be disposed of from the construction and demolition sector in the EU annually (EC 2011). At the current rate of usage, 10,431 tonnes of HBCD is each year incorporated into new flame retarded products in the EU and at least 28,000 tonnes globally, which will become waste in the future. According to the Annex F submissions developing countries have little more than general information on the amounts and applications of HBCD imported in articles.

98. Emission reduction measures and use of best practices could be required in the production of HBCD for potential specific exemptions and use therein to reduce HBCD releases to the environment from these uses. The costs of emission reduction programmes initiated by the European HBCD and polystyrene manufacturers are highly dependent on the company operations (BSEF 2011).

99. For textile back coating and HIPS, several alternatives are already in use suggesting alternatives are economically feasible. Economical viability of the intumescent systems has, however, been questioned by the HBCD Industry. For the EU, the total incremental costs at the production level of replacing the HBCD in HIPS in all EEE have been estimated in the range of 1-10 million €/year if HBCD is replaced with other brominated flame retardants and 5-25 million €/year if the HIPS/HBCD is replaced by copolymers with non-halogenated flame retardants. The costs may decrease over the years as a result of a larger market for the alternatives (DEPA 2010).

100. In controlled burning of waste, the control measures and application of BAT/BEP to address other by-products from incineration also reduce by-product emissions of HBCD and brominated dioxins and furans. There are no additional costs involved for the industry.

101. Fish, particularly fatty carnivorous fish placed at the higher end of the food chain, is an important source for human exposure (Polder et al. 2008, Thomsen et al. 2003). Among all dietary samples, the highest HBCD concentrations (up to 9.4 ng/g wt w) have been reported for fish (Knutzen et al. 2008; Remberger et al. 2004; Allchin and Morris 2003). The phase-out of HBCD could thus have a positive impact on fisheries and aquaculture and could in addition be of general benefit to consumers. Fisheries and aquaculture is an important industry worldwide and contamination of fish may be economically harmful to the industry.

2.4.4 Movement towards sustainable development

102. Controlling the risks posed by chemicals is an important part in working towards a sustainable society. Increased knowledge about fires enables better decision-making in order to ensure a high level of protection from fires as well as from dangerous substances (KEMI 2006). A move towards more environmentally sound flame retardants or non-chemical alternatives (alternative materials/product redesign) is a more sustainable approach, since it represents less hazard to health and to the environment. This will also represent a lower cost for society on a longer term and the development of a green economy, avoiding the cost associated with hazardous chemicals (cost for waste management, reduced health, cost of remediation of contaminated sites etc.) and stimulating the industry sectors with sustainable production and use. There are joint initiatives between authorities and industry to move to more sustainable use of flame retardants. The Green Flame™ is a voluntary system for simultaneously assessing products, in relation to environment and health quality, when involved in fires (www.sp.se/en/index/services/greenflame). It is open to all kinds of different products and will create incentives for manufacturers who design products that perform better than the standards applicable to them. The intention is that the Green Flame™ system will provide competitive advantages to the companies that possess the competence and determination to develop consumer products that represent a major improvement in fire safety and environmental quality.

⁷ The assumption in the estimation is that the consumption declines continuously after 2013 until 2017 when the consumption will be zero.

2.5. Other considerations

103. USEPA has convened a multi-stakeholder partnership to explore the human health and environmental profiles of likely and safer alternatives to HBCD. In addition, a Toxicological Review of HBCD is currently being developed by the Integrated Risk Information System (IRIS) of the USEPA.

<http://www.epa.gov/dfe/pubs/projects/hbcd/index.htm>

<http://www.epa.gov/iris/index.html>

104. European Commission has funded a project where a prototypical case study on substitution options for specific brominated flame retardants is made. Although HBCD is not included, the project aims to deliver a comprehensive dataset on viability of production and application, environmental safety, and a life cycle assessment of the alternative flame retardants (FRs).

<http://www.enfiro.com/index.html>

105. The industry voluntary actions to reduce emissions of HBCD in Europe are described at:

<http://www.bsef.com/our-substances/hbcd/voluntary-emissions-reduction-programme-vecap-and-secure> <http://www.vecap.info/>

106. The 'Europe-wide Monitoring of the Brominated Flame Retardant HBCD in Fish, Bird Eggs and Suspended Particulate Matter (SPM) between 2007-2016 by a team from Fraunhofer Institute for Molecular Biology and Applied Ecology, Universität Trier and the Free university of Berlin. The project is sponsored by the 'Industry Working Group for HBCD', a sector group of the European Chemical Industry Council (CEFIC)

http://www.ime.fraunhofer.de/fhg/Images/summary_environmental_HBCD_monitoring_in_European_fish_new_tcm279-177322.pdf

107. HBCD monitoring information is available from Europe, North America and Asia. To follow the effectiveness of the potential actions, HBCD should be added to the existing POP monitoring activities.

3. Synthesis of information

3.1 Summary of risk profile information

108. The commercially available brominated flame retardant hexabromocyclododecane (HBCD) is lipophilic, has a high affinity to particulate matter and low water solubility. Depending on the manufacturer and the production method used, technical HBCD consists of 70-95% γ -HBCD and 3-30% of α - and β -HBCD.

109. In biota, HBCD has been found to bioconcentrate, bioaccumulate and to biomagnify at higher trophic levels. High concentrations have been identified in Europe and Japan and in coastal waters of south China, near production sites of HBCD, manufacturing sites of products containing HBCD and waste disposal sites including those whose processes include either recycling, landfilling or incineration.

110. HBCD is persistent in the air and is subject to long-range transport. HBCD is found to be widespread in remote regions such as the Arctic, where concentrations in the atmosphere and top predators are elevated.

111. There is a risk of adverse effects in marine mammals and fish in the vicinity of point sources and in regions with elevated background levels. The measured concentration levels in biota exceed the PNEC for secondary effects of 5 mg/kg wwt in the EU risk assessment of HBCD (European Commission 2008). Levels in birds from European regions with elevated background levels or near local point sources are concluded to lie near the threshold levels for adverse effects.

112. Data from laboratory studies with Japanese quail and American kestrels indicate that HBCD at environmentally relevant doses could cause eggshell thinning, reduced egg production, reduced egg quality and reduced fitness of hatchlings. HBCD is also very toxic to aquatic organisms. In mammals, studies have shown reproductive, developmental and behavioural effects. Recent advances in the knowledge of HBCD-induced toxicity includes a better understanding of the potential of HBCD to interfere with the hypothalamic-pituitary-thyroid (HPT) axis, its potential ability to disrupt normal development, and to affect the central nervous system.

113. Available studies demonstrate that HBCD is well absorbed from the rodent gastro-intestinal tract. In humans HBCD is found in blood, plasma and adipose tissue. Human breast milk data from the 1970s to 2000 show that HBCD levels have increased in this time period. HBCD levels in human milk appear to mirror the market consumption of HBCD.

3.2 Summary of risk management evaluation information

114. HBCD is produced in China, Europe, Japan, and the USA. The known current annual production is approximately 28,000 tonnes per year. The main share of the market volume is used in Europe and China.

115. HBCD has been on the world market since the 1960s. It is used as a flame retardant additive, with the intent of delaying ignition and slowing subsequent fire growth during the service life of vehicles, buildings or articles, as well as while materials are stored. The main uses of HBCD globally are in flame-retarded expanded (EPS) and extruded (XPS) polystyrene foam for insulation and construction, while the use in textile applications and electric and electronic appliances (HIPS) is of a smaller scale. In textiles HBCD is used in back-coating used for furniture upholstery and other interior textiles, including automotive applications.

116. Many countries have already restricted or are in the process of evaluating the risks of HBCD. A number of alternative fire retardants are available to replace HBCD in HIPS and textile back-coating. For EPS and XPS, an alternative chemical called Emerald 3000 was announced in 2011; commercial production is expected to commence in 2012. It is expected, however, to take several years for the whole industry to convert to the use of an alternative flame retardant, with production processes and products that will need to be optimised and new product certifications obtained across a large industry.

117. In some countries there is a need for flame retarded insulation materials due to the country-specific fire safety requirements. In some countries HBCD has effectively already been phased out. In those countries the fire safety regulations do not require treatment with a flame retardant, and the same level of fire safety is achieved by other alternatives, that are technically feasible and also commercially available.

118. There are also technically feasible and commercially available alternatives to the different materials HBCD is used in on the market. The alternatives include flame retardant substitution, resin/material substitution and product redesign.

119. HBCD may be released to air, water, soil and sediment during all stages of its life cycle; production and manufacturing, processing, transportation, use, handling, storage or containment, and from disposal of the substance or products containing the substance. Releases may be from point sources or may be diffuse releases from manufactured product usage. Releases of HBCD to the environment during manufacture and formulation and from products during end use have been estimated to be small in the EU. The end use releases to waste water and surface water are dominated by textile coatings. However, release estimates during consumer use are highly uncertain.

120. Wastes containing HBCD are of concern because increasing amounts of HBCD-containing wastes in landfills and other locations could be a long-term source of HBCD emissions to the environment. If listed in the Convention, stockpiles and wastes containing HBCD would be subject to the provisions in Article 6 and would have to be managed in an environmentally sound manner. HBCD wastes include production wastes, waste insulation boards, building and renovation wastes, and from other less-commonly used applications such as electrical and electronic products and textiles. The process of remodelling and demolition of buildings leads to concerns that installed building materials containing HBCD will continue emissions in the future, unless properly managed by future generations. The amount of material becoming waste in the future will increase due to continuing use of HBCD at present.

121. HBCD containing products and articles are commonly recycled upon becoming waste. This can lead to HBCD contamination of products that will be difficult to identify. In developing countries, electrical and electronic appliances containing HBCD and other toxic substances are often recycled under conditions which results in a relatively high release of HBCD to the environment and contamination of the sites (Zhang et al. 2009), and exposure of workers (Tue et al. 2010). Open burning and dump sites are common destinations for HBCD-containing articles and electronic wastes (Malarvannan et al. 2009; Polder et al 2008).

122. Controlled incineration is one way to dispose of waste containing HBCD. In the case of uncontrolled fires (accidental fire) and with co-combustion at lower temperatures or in not well functioning incinerators there is a risk of formation of polybrominated dioxins (PBDDs) and furans

(PBDFs) (ECHA 2009). Currently in many countries landfilling is the most common form of waste disposal, leading to HBCD containing waste accumulating in the landfills.

3.3 Suggested risk management measures

123. The suggested control measure is that HBCD be listed under the Convention. To allow for certain time-limited critical uses of HBCD, a specific exemption for use of HBCD in EPS/XPS could be given together with a description of the conditions for production and for these uses. Such a listing would effectively end the use of HBCD as a flame retardant in highly emissive textile applications and in HIPS, for which alternatives are widely available, and in EPS/XPS, when chemical drop-in substitutes are phased in. For the chemical substitute for flame retarded EPS/XPS, there is still a clear need for time for testing, validation, qualification, production capacity adjustments and commercialization to enable a smooth transition. It will, therefore, take several years before a sufficient volume of HBCD alternatives covering the needs of the market becomes commercially available.

124. Listing of HBCD under the Convention would be consistent with the POPs properties of this intentionally produced substance and would send a clear signal that production and use of HBCD must be phased out. Such a listing may have implications for countries in light of ongoing uses where alternative substances or alternative methods need to be phased in.

125. Stockpiles and waste containing HBCD would be subject to the provisions in Article 6.

4. Concluding statement

126. Having decided that hexabromocyclododecane (HBCD) is likely, as a result of long-range environmental transport, to lead to significant adverse effects on human health and/or the environment such that global action is warranted;

127. Having prepared a risk management evaluation and considered the management options;

128. The Persistent Organic Pollutants Review Committee recommends, in accordance with paragraph 9 of Article 8 of the Convention, the Conference of the Parties to the Stockholm Convention to consider listing and specifying the related control measures of hexabromocyclododecane⁸ under the Stockholm Convention.

⁸ "Hexabromocyclododecane" 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).

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