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

Addendum

Risk management evaluation on decabromodiphenyl ether (commercial mixture, c-decaBDE)

At its eleventh meeting, by its decision POPRC-11/1, the Persistent Organic Pollutants Review Committee adopted a risk management evaluation for decabromodiphenyl ether (commercial mixture, c-decaBDE) on the basis of the draft contained in the note by the secretariat (UNEP/POPS/POPRC.11/2). The text of the risk management evaluation, as amended, is set out in the annex to the present addendum. It has not been formally edited.

Annex

DECABROMODIPHENYL ETHER

(commercial mixture, c-decaBDE)

RISK MANAGEMENT EVALUATION

Prepared by the intersessional working group on decabromodiphenyl ether
Persistent Organic Pollutants Review Committee

October 2015

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Executive summary

1. In 2013, Norway submitted a proposal to list commercial decabromodiphenyl ether (c-decaBDE) as a persistent organic pollutant under the Stockholm Convention. In 2014, at the 10th meeting of the POPs Review Committee, it was decided that BDE-209, the main constituent of c-decaBDE 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. An ad hoc working group was established to prepare a risk management evaluation for c-decaBDE, in accordance with Annex F of the Convention, for consideration by POPs Review Committee at its 11th meeting in October 2015.

2. C-decaBDE is an intentionally produced chemical consisting of the fully brominated decaBDE congener or BDE-209 ($\geq$90-97%), with small amounts of nona- and octa-bromodiphenyl ether. C-decaBDE has been under investigation for its potential health and environmental impacts for more than a decade and has been subject to restrictions and voluntary risk management actions in some countries and regions, as well as by some companies. Production of c-decaBDE but is still ongoing in a few countries globally.

3. C-decaBDE is an additive flame retardant that has a variety of applications including in plastics, textiles, adhesives, sealants, coatings and inks. C-decaBDE containing plastics are used in electrical and electronic equipment, wires and cables, pipes and carpets. In textiles, c-decaBDE is mainly used in upholstery, window blinds, curtains and mattresses for public and domestic buildings, and in the transportation sector. The amount of c-decaBDE used in plastics and textiles globally varies but up to about 90% of c-decaBDE ends up in plastic and plastics used in electronics while the remainder is used in coated textiles, upholstered furniture and mattresses.

4. Emissions of c-decaBDE to the environment occur at all its life cycle stages, but are assumed to be highest during service life and in the waste phase. The average service life for electric and electronic equipment is about 10 years hence c-decaBDE will continue to be released to the environment through articles in use for years to come. The most efficient control measure to reduce the releases of c-decaBDE and its main constituent BDE-209, would be to list BDE-209 (c-decaBDE) in Annex A of the Convention without specific exemptions. Furthermore, efficient control measures for the handling of waste containing c-decaBDE will also be essential. Due to the historical- and present use of c-decaBDE as a flame retardant, a large number of products in use will become waste in the future. Controlled incineration of waste containing c-decaBDE at high temperatures is one way of destruction, with systems to remove possible brominated furan/dioxin compounds produced in the process, along with continuous monitoring and strict compliance with Convention BAT/BEP guidelines and environmentally sound treatment of fly ashes. Other means are described in document UNEP/POP/COP.7/INF/22 which also provides constraints in recycling.

5. According to Article 6 of the Convention, waste shall be disposed of in such a way that the POP content is destroyed or irreversibly transformed so that it does not exhibit the characteristics of POPs, or otherwise disposed of in an environmentally sound manner when destruction or irreversible transformation does not represent the environmentally preferable option or the POP content is low. For this reason, recycling of material containing c-decaBDE above the low POP content limit value is not recommended and should be avoided. Recently, BDE-209 has been detected in a number of articles, made from recycled material, including articles in contact with food. This indicates that it is difficult to control the content of c-decaBDE in plastic material destined for recycling and that recycling may contribute to human exposure to c-decaBDE. Monitoring data also shows that recycling contributes to significant environmental pollution and health risks for local populations, particularly in developing countries where recycling occurs in the informal sector. Technical solutions are available in the waste sector to achieve more sustainable waste management e.g. by sorting out components containing hazardous chemicals are not available on an industrial scale and especially in developing countries. A restriction on c-decaBDE might have an economic impact on the recycling industry, but the economic costs and benefits are hard to predict. At present, recycling of c-decaBDE containing plastics and textiles is not known to occur to a great extent and available information suggests that the socioeconomic impact of not recycling c-decaBDE may be limited.

6. On a country or regional basis an analysis of the economic impacts to recycling facilities needs to be undertaken. What could be defined as an optimal solution depends very much on the economic and cultural context in which the system operates. The cost of labour, the structure of the economy including the important informal sector, the existing regulatory framework and the possibilities and limits of law enforcement have to be taken into account in order to find solutions that can improve the situation with regard to environmental impacts, occupational hazards and economic revenue.

7. Based on the information submitted during the risk management evaluation and the collective experience reported, there may be challenges for some sectors, i.e., legacy spare parts for the aerospace and automotive industries. Some parties identified challenges for recycling. Because of the concerns about articles, products in use, and recycled products containing decaBDE being exported especially to developing countries and countries with economies in transition, other experts opposed recycling exemption due to lack of capacity to identify and analyse products containing deca BDE. Additional risk management measures could include an obligation to label new articles that contains decaBDE.

8. However, a number of non-POP chemical alternatives are already on the market for the substitution of c-decaBDE in plastics and textiles. Furthermore, non-chemical alternatives and technical solutions such as non-flammable materials and physical barriers, respectively, are also available. Annex F information and other available information indicates that textile-, furniture- and electronics markets are in transition away from the use of c-decaBDE and that substitutions have been performed or are in progress for most, if not all, known applications.

9. A positive impact on human health and the environment can be expected from a global reduction or elimination of c-decaBDE. BDE-209, the main constituent of c-decaBDE, and its degradation products is widely detected in the indoor and outdoor environments and is found in some organisms at levels close to or at reported effect concentrations for developmental-, neurotoxic-, and endocrine disruptive effects.

10. The 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 the decabromodiphenyl ether component (BDE-209) of c-decaBDE in Annex A with specific exemptions for some critical legacy spare parts that still need to be defined in the automotive and aerospace industries.

1. Introduction

11. On 13 May 2013, Norway as a Party to the Stockholm Convention, submitted a proposal to list decabromodiphenyl ether (commercial mixture, c-decaBDE) in Annexes A, B and/or C to the Convention. The proposal (UNEP/POPS/POPRC.9/2) was submitted in accordance with Article 8 of the Convention and was reviewed by the POPs Review Committee (POPRC) at its ninth meeting in October 2013, where the Committee agreed that the criteria in Annex D were met. At its tenth meeting in October 2014, the Committee evaluated the draft risk profile for c-decaBDE (UNEP/POPS/POPRC.10/10/Add.2) in accordance with Annex E, adopted this (UNEP/POPS/POPRC.10/10) and decided to establish an intersessional working group to prepare a risk management evaluation for the substance (Decision POPRC-10/2).

12. In the present document, the abbreviation c-decaBDE is used for technical or commercial decaBDE products. Decabromodiphenyl ether (BDE-209) refers to the single fully brominated polybromiated diphenylether (PBDE), which elsewhere sometimes is denoted as decaBDE.

1.1 Chemical identity of the proposed substance

13. The risk management evaluation concerns c-decaBDE and its main component, BDE-209. C-decaBDE is a commercial PBDE formulation that is widely used as an additive flame retardant in textiles and plastics, additional uses are in adhesives and in coatings and inks (ECHA 2013b). C-decaBDE consist predominantly of the congener BDE-209 (≥97%), with low levels of other PBDE congeners such as nonabromodiphenyl ether (0.3-3%) and octabromodiphenyl ether (0-0.04%). Chen et al. (2007) reported that the octaBDE and nonaBDE content of two c-decaBDE products from China was in the range 8.2 to 10.4% suggesting that a higher degree of impurities may be found in some commercial mixtures. Historically a range of 77.4-98% of BDE-209, and smaller amounts of the congeners of nonaBDE (0.3-21.8%) and octaBDE (0-0.85%) have been reported (ECHA, 2012a; U.S. EPA, 2008; RPA, 2014). Total tri-, tetra-, penta-, hexa- and heptaBDEs are typically present at concentrations below 0.0039% w/w (ECB 2002; ECHA 2012a). Trace amounts of other compounds, thought to be hydroxybrominated diphenyl compounds can also be present as impurities. In addition, polybrominated dibenzo-p-dioxins and polybrominated dibenzofurans (PBDD/Fs) have been reported as impurities in some c-decaBDE products (Ren et al., 2011).

14. Chemical data on the main component of c-decaBDE, BDE-209, are presented in Figure 1 and in Tables 1 and 2 below (ECHA, 2012a). According to available information, c-decaBDE is currently available from several producers and suppliers globally (Ren et al., 2013; RPA, 2014) and is marketed under different trade names (Table 1).

Figure 1. Structural formula

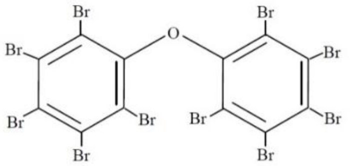

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Table 1
Chemical identity of c-decaBDE and its main constituent BDE-209

CAS number:	1163-19-5[1]
CAS name:	Benzene, 1,1'-oxybis[2,3,4,5,6-pentabromo-]
IUPAC name:	2,3,4,5,6-Pentabromo-1-(2,3,4,5,6-pentabromophenoxy)benzene
EC number:	214-604-9
EC name:	Bis(pentabromophenyl) ether
Molecular formula:	$C_{12}Br_{10}O$
Molecular weight:	959.2 g/mole
Synonyms:	decabromodiphenyl ether, decabromodiphenyl oxide, bis(pentabromophenyl) oxide, decabromo biphenyl oxide, decabromo phenoxybenzene, benzene 1,1' oxybis-, decabromo derivative, decaBDE, DBDPE[2], DBBE, DBBO, DBDPO
Trade names	DE-83R, DE-83, Bromkal 82-ODE, Bromkal 70-5, Saytex 102 E, FR1210, Flamecut 110R. FR-300-BA, which was produced in the 1970s, is no longer commercially available (ECA, 2010).

[1] In the past CAS no. 109945-70-2, 145538-74-5 and 1201677-32-8were also used. These CAS no. have now formally been deleted, but may still be in practical use by some suppliers and manufacturers.
[2] DBDPE is also used as an abbreviation for Decabromodiphenyl Ethane CAS no. 84852-53-9.

Table 2
Overview of relevant physicochemical properties of c-decaBDE and its main constituent BDE-209

Property	**Value**	**Reference**
Physical state at 20°C and 101.3 kPa	Fine, white to off-white crystalline powder	ECB (2002)
Melting/freezing point	300-310°C	Dead Sea Bromine Group (1993), cited in ECB (2002)
Boiling point	Decomposes at >320°C	Dead Sea Bromine Group (1993), cited in ECB (2002)
Vapour pressure	4.63×10^{-6} Pa at 21°C	Wildlife International Ltd (1997), cited in ECB (2002)
Water solubility	<0.1 µg/L at 25°C (column elution method)	Stenzel and Markley (1997), cited in ECB (2002)
n-Octanol/water partition coefficient, K_{ow} (log value)	6.27 (measured – generator column method) 9.97 (estimated using an HPLC method)	MacGregor and Nixon (1997), Watanabe and Tatsukawa (1990), respectively, cited in ECB (2002)
Octanol-air partition coefficient K_{oa} (log value)	13.1	Kelly et al. (2007)

1.2 Conclusions of the Review Committee, Annex E information

15. At its 10th meeting the Committee concluded that, "C-decaBDE is a synthetic substance with no known natural occurrence that is used as a flame retardant in many applications worldwide. Releases of c-decaBDE to the environment are continuing in all regions investigated. BDE-209

(or decaBDE), the main constituent of c-decaBDE is persistent in the environment and bioaccumulates and biomagnifies in several species of fish, birds and mammals as well as in food webs. There is evidence for adverse effects to critical endpoints including reproduction, survival, nerve- and endocrine systems. C-decaBDE is also degraded to lower brominated PBDEs, with known PBT/vPvB and POP properties. Lower brominated congeners contribute in the outcome of BDE-209 toxicity. Due to debromination and historical reservoirs of c-penta- and c-octaBDE congeners in the environment, organisms are exposed to a complex mixture of PBDEs that in combination pose a higher risk than BDE-209 alone. Measured BDE-209 levels in some species of biota, including higher trophic levels such as birds and mammals in source and remote regions are close to reported effect concentrations and indicate that BDE-209 together with other PBDEs pose a significant concern for human health and the environment. C-decaBDE with its main constituent BDE-209 is likely, therefore, 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”.

16. 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 decaBDE in accordance with Annex F of the Convention for consideration at its next meeting.

1.3 Data sources

17. The risk management evaluation was developed using information contained in the risk profile (UNEP/POPS/POPRC.10/10/Add.2) and Annex F information submitted by Parties and other stakeholders including non-governmental organizations as well as industry. Eight Parties and Observers submitted information: Australia, Canada, China, Japan, Mali, The Netherlands, Serbia, and USA. Four non-governmental Observers submitted information; European Automobile Manufacturers Association (ACEA), Bromine Science and Environmental Forum (BSEF), ICL-Industrial Products, Paxymer AB as well as the International POPs Elimination Network (IPEN). All Annex F submissions are available on the Convention website (www.pops.int).

18. Scientific literature obtained from scientific databases such as ISI Web of Science and PubMed was included as well as "grey" literature such as government reports, risk- and hazard assessments, industry fact sheets etc.

1.4 Status of the chemical under international conventions and forums

19. In 1992, brominated flame retardants (BFRs) were given priority in the Convention for the Protection of the Marine Environment of the North-East Atlantic (OSPAR) action plan. In 1998 c-decaBDE along with the other PBDEs was included in the list of "Chemicals for Priority Action" as well in the Joint Assessment and Monitoring Programme in OSPAR. OSPAR has promoted actions in the EU on risk-reduction strategies for c-decaBDE and electronic waste legislation.

20. In 1995, OECD Member countries agreed to oversee a voluntary industry commitment (VIC) by some of the global manufacturers of BFRs, among them c-decaBDE, to take certain risk management actions. The VIC was implemented in the United States, Europe and Japan. C-decaBDE production has since ceased in Europe and continues to be phased out in the United States. In parallel to this work, OECD conducted an investigation of the waste management practices in member countries with respect to products containing BFRs. The results of this investigation are documented in the Report on the Incineration of Products Containing Brominated Flame Retardants (OECD 1998). A Screening Information Data Sets (SIDS) Initial Assessment Profile (SIAP) on BDE-209 was prepared under the Environment, Health and Safety (EHS) Programme of the OECD and adopted by SIAM 16 and later endorsed by the OECD Joint Meeting in 2003. The Hazard/Risk Information Sheets for c-decaBDE and four other BFRs were updated in 2005, 2008 and 2009 (OECD 2014). PBDEs, including BDE-209, are chemicals of concern due to potential for endocrine disruption in the WHO/UNEP "State of the science of endocrine disrupting chemicals" (WHO/UNEP 2013).

1.5 Any national or regional control actions taken

21. C-decaBDE has been under scrutiny for its potential health and environmental impacts for more than a decade. Steps to restrict the use of c-decaBDE have been taken in some countries and regions, as well as by some of the major electronic companies (for an overview: UNEP/POPS/POPRC.9/2, Ren et al., 2011).

22. In Europe, regulations on c-decaBDE are in place in the EU and Norway. With the European Restriction of Hazardous Substances Directive (RoHS), the use of PBDEs, including c-decaBDE was banned in electronic and electrical equipment (EEE) in the EU at concentrations above 0.1% by weight of homogeneous material. Although this legislation came into force in February 2008, medical equipment was initially exempt. In June 2011 however, this exemption was removed and medical

devices fall within the scope of RoHS with effect from 22 July 2014. In 2012 c-decaBDE was identified as a PBT/vPvB (persistent, bioaccumulative and toxic/ very persistent, very bioaccumulative) substance in the EU and included in the Candidate List of substances of very high concern (SVHCs) under the Registration, Evaluation, Authorisation and Restriction of Chemicals Regulation (REACH). The EU are now considering a proposal to restrict the manufacture, uses and placing on the market of c-decaBDE as a substance and as a constituent of other substances, or in mixtures, if the concentration is equal or greater than 0.1% by weight. Articles containing c-decaBDE in concentrations greater than 0.1% by weight are also proposed to be restricted. However, derogations are suggested for articles on the second hand market, for EEE covered by the existing ban for these products, for articles used in the aviation and automotive sectors such as in production, maintenance, repair or modification of any aircraft or component eligible for installation produced in accordance with a type certificate or restricted type certificate (ECHA 2015) and for legacy spare parts used for the repair and maintenance of out of production vehicles. In addition, the available evidence seems to suggest that the proposed restrictions will not have an additional negative impact on the recycling materials. Further information should be collected to confirm this lack of impact on recycling. In Norway production, import, export, placing on the market and use of c-decaBDE at concentrations 0.1 % or more as a substance and in preparations and in articles are prohibited. The ban, which entered into force in 2008, includes all uses except the use of c-decaBDE in means of transportation. In addition, c-decaBDE is included in the Waste regulations which prescribes that waste containing c-decaBDE at or above 0.25% must be handled as hazardous waste.

23. In North America, the first restriction was adopted in Canada in 2008 with a ban on manufacture of PBDEs, including c-decaBDE, under the PBDE Regulations (Environment Canada 2008). In August 2010, Environment Canada and Health Canada published a Final Revised Risk Management Strategy for PBDEs which reiterated the objective of reducing the concentration of PBDEs in the Canadian environment to the lowest level possible. This resulted in agreement with three large worldwide producers of c-decaBDE to voluntarily phase-out the import of c-decaBDE to Canada. The voluntary agreement included a phase-out of c-decaBDE exports and sales for EEE by the end of 2010, for transportation and military uses by the end of 2013 and for all other uses by the end of 2012 (Environment Canada 2010). On April 4 2015, Canada published proposed regulations to prohibit the use, sale, offer for sale and import of tetraBDE, pentaBDE, hexaBDE, heptaBDE, octaBDE, nonaBDE and decaBDE and products containing them (e.g. resins, mixtures, polymers). The regulatory proposal excludes manufactured items. Canada has consulted on its plan to regulate PBDEs in products other than in mixtures, polymers and resins: http://www.chemicalsubstanceschimiques.gc.ca/fact-fait/glance-bref/pbde-eng.php. A voluntary phase out is also ongoing in the U.S. On December 17, 2009, as a result of negotiations with the United States Environment Protection Agency (U.S. EPA), the two U.S. producers of c-decaBDE and the largest U.S. importer announced commitments to voluntary phase out c-decaBDE in the U.S. (Annex F USA). The commitments consisted of reductions in the domestic manufacture, import, and sales of c-decaBDE starting in 2010. The U.S. EPA then encouraged other importers of c-decaBDE to join this initiative. As part of this encouragement, the U.S. EPA developed a Design for the Environment and Green Chemistry alternatives assessment for c-decaBDE to aid users in selecting suitable alternatives. In addition, the U.S. EPA proposed an update to the PBDE Significant New Use Rule (SNUR) and simultaneously proposed a Toxic Substances Control Act (TSCA) section 4 test rule for c-pentaBDE, c-octaBDE, and c-decaBDE. As proposed, the test rule would require development of information necessary to determine the effects of manufacturing, processing, or other activities involving these c-PBDEs on human health or the environment. In the proposal, the U.S. EPA stated its intention to promulgate the SNUR for anyone who intends to manufacture (including import) or process any of the chemicals for an activity that is designated as a significant new use, and to promulgate a TSCA section 4 test rule if it determines that manufacture (including import) or processing of c-PBDEs, including in articles, has not ceased by December 31, 2013. In addition, the U.S. EPA helped establish the Furniture Flame Retardancy Partnership (as part of the U.S. EPA's Design for the Environment Program). This is a joint venture between the Furniture Industry, Chemical Manufacturers, Environmental Groups, and the U.S. EPA to better understand fire safety options for the furniture industry. This type of group has helped the textile and foam industries to quickly transition away from BFRs (U.S. EPA, 2014b). Additionally, in the U.S., several states have also imposed restrictions on the manufacture and/or use of c-decaBDE in certain applications, including in mattresses, mattress pads and other bedding products, seating, furniture and electronic products (U.S. EPA, 2014a). Up-to-date information on state regulations can be found in the U.S. State-level Chemicals Policy Database, see http://www.chemicalspolicy.org/chemicalspolicy.us.state.database.php (LSCP 2015).

24. In Asia, restrictions have been adopted in China, India and Korea. In the revision of the Chinese RoHS legislation (Administrative Measure on the Control of Pollution Caused by Electronic Information Products) a restriction on the use of c-decaBDE in EEE was adopted (BSEF 2012).

According to Annex F information from China, PBDEs are not allowed in EEE at concentrations above 0.1% by weight for environmental labelling of products. E-waste must be handled in accordance with the legislation on the Waste of Electrical and Electronic Equipment (Jinhui et al., 2015; BSEF, 2015a). Furthermore, it has been reported that in China e-waste containing PBDE FRs should be separated out. It should be disposed of as hazardous waste**.** (Jinhui et al. 2015)**.** China also recently announced that they will prohibit the use of PBDEs in cars with a concentration limit of 0.1 % from 1 January 2016. The restriction will apply to car parts for passenger cars containing fewer than nine seats (category 1M vehicles). The standard applies only to Chinese manufacturers and international companies involved in joint ventures with Chinese manufacturers. For existing models already on the road or in production, the standard will be phased in and will apply from 1 January 2018 (Chemical Watch 2015). Korea implemented a law in 2008, which covers end-of-life and restrictions on electronic products and vehicles. Exemptions, limit values and restricted substances are the same as the EU RoHS Directive. C-decaBDE is exempted from the list of hazardous substances in polymeric applications under the Recycling of Resource in Electronic Equipment and Automobiles' Regulation (BSEF 2012). Similarly to the EU end of life vehicle directive, legacy spare parts for out of production vehicles are exempted from this restriction. In India, the e-waste (management and handling) Rules came into effect in May 2012. The chapter on the Restriction of hazardous substances under the e-waste rules restricts the use of PBDEs in EEE with a threshold limit of 0.1% (BSEF, 2012, 2015b). In Japan, under the Chemical Substances Control Law, the annual production or import volumes of BDE-209 have to be reported along with shipment volumes (Annex F, Japan).

25. In addition to the above measures taken by countries, initiatives to voluntarily phase-out c-decaBDE have been taken by industry. The member companies of the BSEF moreover agreed with the U.S. EPA and Canadian authorities to voluntarily phase out production, import and sales of c-decaBDE in the United States and Canada as of the end of 2013. Also, the automotive industry represented by ACEA has committed in its latest input into the public SEAC consultation on the EU REACH Restriction to completely phase out DecaBDE globally, latest by mid of 2018 for current production and new developments. Phase out is also ongoing in North America and China. Many electronics firms have already eliminated or committed to eliminating c-decaBDE in accordance with the EU RoHS, including Philips, Electrolux, Sony, Dell, Intel, Sharp, Apple and Hewlett Packard (Renet al., 2011). Other industrial stakeholders have also implemented/ launched voluntary initiatives. In Germany there has been a voluntary agreement for the use and production of all PBDEs on the part of the German industry since 1986 because of concerns about brominated dioxins/furans that could be present in products (Leisewitz &Schwarz, 2001). The commitment was only of limited effect (Leisewitz and Schwarz, 2001). Furthermore, large global furniture producers, have phased-out the use PBDEs including c-decaBDE and several mattress producers globally now offer PBDE-free mattresses (see e.g. http://mattresszine.com/mattress-news/pbde-free-manufacturer-product-list/). In addition there are voluntary initiatives to control and reduce potential emissions of commercial decaBDE into the environment. The European Flame Retardant Association (EFRA) together with the industry's global organisation, the Bromine Science and Environmental Forum (BSEF), has moreover launched a voluntary initiative whereby member companies aim to manage, monitor and minimize industrial emissions of high production volume BFRs, including decaBDE through partnership with the supply chain (VECAP, 2012). This program, called the Voluntary Emissions Control Action Program (VECAP) started in Europe in 2004 but has later also been introduced in North America and in Japan.

2. Summary information relevant to the risk management evaluation

26. As discussed in the risk profile, c-decaBDE is produced in high quantities worldwide (UNEP/POPS/POPRC.10/10/Add.2, UNEP/POPS/POPRC.10/INF/5). In the past, c-decaBDE constituted 75-80% of the total global production of PBDEs (KemI, 2005; RPA, 2014). Furthermore, the total global amount of c-decaBDE produced in the period 1970-2005 was between 1.1-1.25 million tonnes, similar to the scale of production of PCBs (Breivik, 2002).

27. The many uses and applications of c-decaBDE is reviewed in the risk profile (UNEP/POPS/POPRC.10/10/Add.2, see also Table 1, UNEP/POPS/POPRC.11/INF/6) but can be roughly divided into two main categories – in plastics polymers and in textiles. As discussed in detail in the risk profile the c-decaBDE use within these applications varies between different countries and regions. Further as described in the risk profile, emissions of c-decaBDE to the environment occur at all its life cycle stages; during production, formulation and other first- and second-line uses at industrial/professional sites, as well as during service life of articles, their disposal as waste and during recycling operations (UNEP/POPS/POPRC.10/10/Add.2 and references within). The release and distribution of c-decaBDE to the environment via these routes is confirmed by monitoring data (UNEP/POPS/POPRC.10/INF/5), and are likely to occur over a long time-frame.

28. A number of emission assessments have been performed based on modelling (UK EA, 2009; RPA, 2014; ECHA, 2014a; Earnshaw et al., 2013). The assessments collectively indicate that emissions of c-decaBDE during service life and upon disposal of products (as waste) are the most important sources of release, and are in line with reported environmental monitoring data (UNEP/POPS/POPRC.10/10/Add.2). C-decaBDE also contributes to emissions of lower brominated PBDEs as well as brominated dioxins and furans (PBDD/F) which are unintentionally formed throughout the whole lifecycle of PBDEs like c-decaBDE (UNEP/POPS/POPRC.10/10/Add.2).

29. Control measures should be considered for all the above described sources of exposure and releases including production, use and in the waste management phase.

2.1 Identification of possible control measures

30. The objective of the Stockholm Convention (Article 1) is to protect human health and the environment from POPs. This may be achieved by listing c-decaBDE in Annex A, B and/ or C in the Convention, possibly accompanied with exemptions for certain uses and/or acceptable purposes. Given that the main constituent of c-decaBDE, BDE-209, 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.10/10/Add.2, UNEP/POPS/POPRC.10/10), and mindful of the precautionary approach set forth in Article 1 of the Convention, the aim of any risk reduction strategy for c-decaBDE should be to as far as possible reduce and eliminate emissions and releases of c-decaBDE. The most effective control measure would be to list c-decaBDE in Annex A of the Convention with no exemptions for production and use.

31. If c-decaBDE is listed in the Convention, the provisions of Article 6(1)(d)(ii) have to be fulfilled. This means that waste shall be disposed of in such a way that the POP content is destroyed or irreversibly transformed so that it does not exhibit the characteristics of POPs, or otherwise disposed of in an environmentally sound manner when destruction or irreversible transformation does not represent the environmentally preferable option or the POP content is low. Parties should also consider emission reduction measures and the use of best available techniques and best environmental practices (BAT/BEP) in the waste management phase. In addition, Parties shall endeavour to develop appropriate strategies for identifying sites contaminated with c-decaBDE. If contaminated sites are identified and remediation is undertaken, it shall be performed in an environmentally sound manner.

32. In the event that the Conference of the Parties agrees on specific exemptions and/or acceptable purposes, emission reduction measures and the use of BAT/BEP during production and manufacture should also be considered. Additional measures linked to potential exemptions and/or acceptable purposes could include a requirement on proper and informative labelling or other means of identification of c-decaBDE-containing new products similar to what was agreed upon when listing HBCD (SC-6/13). Labelling of products containing POPs may be a necessary measure in order to effectively manage products upon becoming wastes. In addition, labelling of POP wastes containers is a basic safety feature and important for the success of any waste management system. Each waste container should be labelled to identify the container (e.g., ID number), the POP present and the hazard level (Basel Convention, 2015b).

33. Some Parties have identified the need for a possible exemption for recycling in line with listed BDEs. Noting that there are concerns about articles, products in use, and recycled products containing decaBDE being exported especially to developing countries and countries with economies in transition, African experts oppose a recycling exemption due to lack of capacity to identify and analyse products containing deca BDE. Furthermore, some transportation industry associations have identified a need for exemptions for the use of c-decaBDE in the repair, and modifications of aircrafts under existing type certificates and for functional legacy spare parts used for the repair and maintenance of out of production vehicles. The need for these exemptions has also been proposed under the ongoing restriction process in the EU where an exemption for the automotive industry is supported by SEAC. The Canadian Vehicle Manufacturer’s Association raises a concern for a ban on production and use of c-decaBDE due to the requirement to provide service and replacement parts for vehicles already on the market. Further, according to The Boeing Company and the Aerospace and Defence industries Association of Europe, c-decaBDE is largely substituted in newer products, but presently not for all uses. In addition, the aviation and aerospace industry indicated a need for use of c-decaBDE as a FR in components and spare parts in airplanes including a range of polymer, textile and electrical items. The Automotive Industry represented by ACEA has requested an exemption for legacy spare parts with functional properties. Parts only with decorative properties may not be considered under the exemption. Their request is related to the testing requirements of original vehicles which are no longer in mass production and often have not been for quite some time, the possibility of testing does not exist in particular for functional components. It is furthermore likely that

manufacturers of spare parts of such functional components will stop their manufacture. This can ultimately result in unavailable or untested and thus dangerous replacement parts, or non-compliance with national obligations to deliver such parts for at least 10 years after mass production. In a worst case, vehicles may not be repairable and thus would have to be wasted.

34. C-decaBDE phase-out could include FR substitution, resin/material substitution and product redesign as well as re-evaluation of fire-safety requirements. As further discussed in chapter 2.3 of this document, alternatives, although with different hazard profiles, to all uses of c-decaBDE are available and accessible (ECHA 2014a; U.S. EPA, 2014a). Moreover, for a wide range of the applications where c-decaBDE is used other FRs have already replaced c-decaBDE (KemI 2005).

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

35. In order to reduce c-decaBDE emissions control measures at all life cycle stages need to be in place.

36. Although waste is recognized as an important source to c-decaBDE emissions, it was recently reported that articles in service life are the largest source of c-decaBDE emissions (RPA, 2014; ECHA, 2014a). For articles, various possible risk management options could be considered. However, the control measure that most effectively will abate global emissions is to globally ban the production and use of c-decaBDE in articles and avoid recycling of products containing c-decaBDE. According to information presented in Section 2.3, the phase-out of c-decaBDE in new products is technically feasible and may be accomplished within a short time-frame given that alternatives for all known uses are available and accessible. Articles in use will however contribute to environmental emissions for some time after a global ban or restriction on use has entered into force. Exactly how long products will continue to be a source of c-decaBDE emissions is difficult to predict. The estimated service life for products containing c-decaBDE varies between products (i.e. EEE or upholstery) and between global regions. Moreover, c-decaBDE is used in such a wide range of products that estimating service lifetimes for each type of product is challenging. An average of 10 year service life was used in European emission estimates (Earnshaw et al., 2013). According to Buekens and Yang (2014) EEE have an average service life of 3-12 years globally, with larger appliances/objects having longer service life. In China, the estimated service life is 10-16 years for most EEE products except computers that are reported to have a service life of no more than 4-6 years (Yuan, 2015). In some developing countries, service lives of different c-decaBDE products may be even longer.

37. In addition to releases from articles during service life, releases from products and articles upon becoming waste are also of significant concern (UK EA 2009; ECHA 2014 a,b). Following a listing of c-decaBDE in the Stockholm Convention a concentration level for low POP content would typically be established in cooperation with the Basel Convention, which also typically will be tasked with determining the methods that constitutes environmentally sound disposal. Introducing waste management measures, including measures for products and articles upon becoming waste, in accordance with Article 6 of the Convention, would ensure that wastes containing c-decaBDE at concentrations above the low POP content are disposed of in an effective and efficient way such that their POPs content is destroyed or otherwise disposed of in an environmentally sound manner. These measures would also address proper waste handling, collection, transportation and storage and ensure that emissions and related exposures to c-decaBDE from waste are minimized. Establishment of the low POP value and the guidelines developed by the Basel Convention will help Parties to dispose of waste containing c-decaBDE in an environmentally sound manner (UNEP/CHW.12/INF/9).

38. C-decaBDE is expected to be present in plastics and textiles in several waste streams such as “End of Life Vehicles” (ELV), e-waste, textile- and mixed waste. Information on c-decaBDE levels in these waste streams is limited. For the global measures to be efficient, proper waste handling could require identifying BDE-209 containing materials to facilitate destruction of the POP content in the waste (UNEP/CHW.12/INF/9). In waste streams, materials containing c-decaBDE could be sorted out, either manually or by use of automated sorting and separation systems. Automated sorting will not always be feasible as c-decaBDE containing materials cannot be readily identified without the use of advanced technical equipment or because the c-decaBDE containing waste is mixed with other materials which makes the sorting more technically challenging. However, establishing an inventory of c-decaBDE containing wastes may assist Parties as well as the industry in identifying waste fractions that may contain c-decaBDE, thereby allowing proper, although more crude sorting of the waste also by manual methods. According to newly published studies by the Nordic Council of Ministers (NCM), e-waste treatment processes with significant low-technology elements, including manual disassembly and separation of e-waste, can currently achieve significantly better plastic recycling than highly mechanised and automated alternatives. Lower-technology approaches carry

relatively higher costs and may otherwise appear unattractive in a sector where technological advance seems vital.

39. Two guidance documents, developed under the Stockholm Convention,[1] have identified common technologies and approaches for identification and sorting out wastes containing polybrominated dipenylethers (PBDEs) listed under the Convention, as well as for their recycling. These methods are compatible with both manual and automated sorting of wastes. The recycling industry, however, in practice separates plastics based on total bromine content, not individual BFRs (UNEP/POPS/POPRC.6/2/Rev.1).

40. A recent Dutch study reported the fate of POP-BDEs (including BDE-209) in plastic waste streams. In general, POP-BDEs were found in very few single cars, or e-waste. However, BDE-209 was frequently found (92-100%) in the shredded material from e-waste or cars and in recycled plastic pellets (100%) at higher concentrations than other POP-BDEs. This is often due to the fact that these waste streams are being mixed during shredding (IVM/IVAM, 2013). In Europe, an extended producer responsibility scheme is formulated in the ELV directive (2000/53/EC) which requires that materials from ELVs are being recycled in order to meet the stringent recycling quota of 85%. Legal recycling obligations are existing or emerging also in other countries (e.g. already existing in Korea and emerging in India). The overall recycling rate of ELV in the EU reaches approximately 85% (EUROSTAT/2015). Sweden reported that plastic from ELVs usually ends up in the Shredder Light Fraction (SLF), which is mainly incinerated, and in some cases specific fractions are being landfilled. In Norway, BDE-209 was identified in car upholstery from Asia, in levels of 1.5-2.5% w/w, and the waste components are considered hazardous if they contain more than 0.25% c-decaBDE and incinerated after shredding. Large plastic parts from ELV in Germany are mainly recycled but about 10% are reused. The SLF with high calorific value is incinerated or used for energy recovery, while the low calorific value fraction, which has higher mineral content, can be used for landfill construction or the back-filling of mines (RPA, 2014). In the recent Dutch study, BDE-209 was not found in European ELV parts but was detected in 59% of the ELV parts of older US and Asian cars assembled before 2001. Analysed and concentrations ranged from < 2 – 23,000 µg/g (IVM/IVAM, 2013 and Tables 2 and 3, respectively, in UNEP/POPS/POPRC.11/INF/6). Collectively these studies illustrate the need to sort out and remove c-decaBDE containing parts prior to destruction (i.e. shredding) and recycling operations might be an important and effective measure to avoid further distribution of c-decaBDE contained in waste. However, it should be noted that separating deca-BDE containing parts can be impractical due to the diversity of deca-BDE containing parts in ELVs. Sorting technologies after shredding that would be able to separate c-decaBDE containing fractions are not available on an industrial scale and especially in developing countries. Policies on extended producer responsibility in which a producer's responsibility for a product is extended to the waste stage of a product's life cycle, could play a key role in implementing these practices. The automotive industry has indicated that existing and emerging recycling quotas in the EU cannot be met without a derogation for ELV recycling.

41. Destruction of c-decaBDE containing waste in accordance with Article 6.1 d(ii) and 6.2 of the Convention would contribute to the elimination of emissions and exposure from waste. Different techniques for handling POPs-containing waste in an environmentally sound manner are available (Basel Convention 2015a, b; Stockholm Convention, 2012a). Controlled incineration, where the FR decomposes in the incineration process, is one way to dispose of waste containing c-decaBDE (ECHA, 2014). Incineration at high temperatures is generally considered the effective manner to destroy POPs like c-decaBDE/PBDEs or products containing these chemicals, such as in hazardous waste incinerators and by cement kiln co-incineration (Basel Convention, 2015a). Experimental evidence shows that under some conditions, including in state-of-the art municipal solid waste incineration facilities, incineration of POPs waste may lead to formation of polybrominated dibenzo-dioxins (PBDD), polybrominated dibenzofurans (PBDF), brominated-chlorinated dibenzo-p-dioxins (PXDD) and dibenzofurans (PXDF) (NCM, 2005; ECA, 2011; Stockholm Convention, 2012a; Weber and Kuch, 2003). These incineration products formed from waste containing c-decaBDE may be destroyed at the very high continuous operating temperatures with their emissions to the environment controlled to some extent via the flue gas treatment systems, though contaminated fly ash will also be formed which requires disposal in a hazardous waste landfill. The incineration efficiency and the operating conditions of the flue gas treatment systems are of great importance to the

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[1] Guidance for the inventory of polybrominated dipenylethers (PBDEs) listed under the Stockholm Convention on POPs; Guidance for the inventory of polybrominated dipenylethers (PBDEs) listed under the Stockholm Convention on POPs.

resulting emissions of dioxins (NCM, 2005; 5EBFRIP, 2005). A number of countries and regions globally have the capacity to incinerate POPs, such as in hazardous waste incinerators or by co-processing in cement kilns. However, a general overview of the global capacity or the capacity for incineration is not available. It has to be considered that technically sufficient incineration capacities for hazardous waste are missing for POPs, even in industrialised countries. As a consequence on a short term basis transportation efforts with related environmental impact have to be considered. Other countries such as the Netherlands has over-capacities.

42. Where neither destruction nor irreversible transformation is the environmentally preferable option, for waste with a POP content above the low POP content, other environmentally sound disposal techniques may be used. Specially engineered landfills may be one option, however, the long-term fate of c-decaBDE in landfills is not well understood and landfills are believed to be the most prominent c-decaBDE emission source from waste (ECHA, 2014a). Monitoring of landfill leachates has shown the presence of BDE-209 (SFT, 2009; Chen et al., 2013) and BDE-209 was also found to be the dominant PBDE congener in landfill sediments (SFT, 2009). However, currently in many countries landfilling is the most common way of waste disposal, leading to c-decaBDE containing waste accumulating in the landfills (U.S. EPA, 2007). Waste containing c-decaBDE above the low POP content level can be landfilled only in specially engineered landfills, designed to prevent leaching and spreading of hazardous chemicals, as described by the Basel Convention guidance (BaselConvention, 1995, 2015a,b; Stockholm Convention, 2012a). Waste containing c-decaBDE below the low POP content level shall be disposed of in an environmentally sound manner in accordance with pertinent national legislation and international rules, standards and guidelines.

43. An additional concern is sludge (biosolids) from wastewater treatment. This sludge may be used as a fertilizer on agricultural soil and has been found to contain BDE-209 in many instances (de Wit et al., 2005; NEA 2012; NERI, 2003; Ricklund et al., 2008a, b; Earnshaw et al., 2013). In many countries sludge from wastewater treatment plants is incinerated or disposed of in landfill due to high-levels of environmental pollutants. If decaBDE concentration in sludge when considered as waste surpasses the low POP limits as defined in the convention text article 6 para 2 c it should be considered as hazardous waste. The prevention and minimization of POP wastes are the first and most important steps in the overall environmentally sound management of such wastes. The Stockholm Convention BAT/BEP Guidelines underlines the importance of source reduction including minimization of quantity of wastes and reduction of toxicity and other hazard characteristics (Stockholm Convention, 2012a). In its Article 4, paragraph 2, the Basel Convention calls on Parties to “ensure that the generation of hazardous wastes and other wastes is reduced to a minimum”. Waste prevention should be the preferred option in any waste management policy. According to the framework for the environmentally sound management of hazardous wastes and other waste, the need to manage wastes and/or the risks and costs associated with doing so are reduced by not generating wastes and ensuring that generated wastes are less hazardous (UNEP, 2013a).

44. Another option of waste management is energy recovery. Plastic containing FR can be destroyed in incinerators for energy recovery. Incineration with energy recovery is a process whereby the energy generated during the combustion of plastic waste is recovered and used to produce heat and/or electricity for domestic or industrial use. In the EU, it has been reported that some of the shredded plastic waste fractions from ELV are incinerated for energy recovery (IVM/IVAM, 2013; RPA, 2014). In Germany in 2010, 40% of the shredded fraction from ELV was incinerated for energy recovery while large plastic parts from ELV were mainly recycled and 10% were reused (RPA, 2014).

45. Prohibiting recycling of materials containing c-decaBDE would contribute to the elimination of risks associated with the recycling process and continuing exposure through products and wastes. Waste management measures in line with Article 6 (d) of the Convention to reduce or eliminate releases from stockpiles and waste, including products and articles upon becoming wastes, containing c-decaBDE above the low POP content will be required to reduce emissions of c-decaBDE. POPRC recommendations on elimination of PBDEs from the waste stream note that the objective is to eliminate PBDEs from the recycling streams as swiftly as possible. Failure to do so will inevitably result in wider human and environmental contamination and the dispersal of PBDEs into matrices from which recovery is not technically or economically feasible and may result in loss of long-term credibility of recycling (Decision POPRC-6/2).

46. Although materials containing c-decaBDE can be recycled several times with only a small loss of the c-decaBDE content (Hamm et al., 2001; as cited in Earnshaw et al., 2013) this practice will continue to spread c-decaBDE to the environment as well as human exposure. The fraction of the recycled plastics used to produce new articles is unknown (ECHA 2014a). However, the more recycled products with low concentrations of BDE-209 there are on the market, the more difficult it will be to identify waste containing c-decaBDE. As a part of the mixed plastic waste to be recycled,

plastic containing c-decaBDE will likely spread into new products that will be difficult to track. BDE-209 has been found in products made from recycled plastics, including food contact articles (FCA) (Samsonek and Puype 2013; Puype et al., 2015). BDE-209 was measured in 10 out of 49 items in concentrations varying between 10 and 1922 mg/kg (Samsoneck and Puype, 2013). In a recent study, BDE-209 was found in FCA such as thermo-cup lids and an egg cutter made from recycled e-waste (Puype et al., 2015). These studies evidently show that products made from recycled material containing c-decaBDE re-enters the market and that some of these, such as toys and FCA, are products that are used in a way that has the potential to pose a threat to human health.

47. Furthermore, some c-decaBDE containing waste ends up in countries that do not have the infrastructure or the technology to dispose waste in an environmental sound manner. Developing countries face economic challenges and lack the infrastructure for sound hazardous waste management, and have particular challenges in this regard (ILO 2012). As environmentally responsible waste management options are highly technological and require high financial investment, there is currently a high level of transboundary, often illegal, movement of e-waste into developing countries for cheaper recycling (SAICM/ICCM.2/INF36). Available estimates of transboundary exports of e-waste are highly variable (reviewed by Breivik et al., 2014). Furthermore, it was reported that of the amount of e-waste collected in developed countries and sent for recycling, 80 per cent ends up being shipped to developing countries to be recycled by hundreds of thousands of informal workers (ILO, 2012). Unregulated recycling processes may pose a risk to workers and the public through exposure to toxic chemicals (U.S. EPA. 2014a; Bi et al.,2007; Qu et al.,2007; Tue et al,. 2010; Tsydenova and Bengtsson 2011). For example, EEE containing c-decaBDE and other toxic substances are often recycled under conditions that results in a relatively high release of BDE-209 to the environment and contamination of the sites (Zhang et al., 2014), children (Xu et al., 2014) and exposure of workers (Tue et al., 2010). As described above, developing countries lack infrastructure for sound hazardous waste management and waste management is typically dealt with in the informal sector using rudimentary techniques,where open burning and dumpsites are common destinations for c-decaBDE-containing articles and electronic wastes (Li et al., 2013; Gao et al,. 2011; ILO, 2012).

48. In the past years, the infrastructure for collecting and recycling electronics has grown considerably, mostly in Europe and parts of Asia, using automated technologies for harvesting metals and plastics from electronics. Between 25% and 30% of the e-waste generated each year is composed of plastic and less than 10% of this plastic is currently recycled. Based on a Dutch mass flow analysis, 22% of the POP-BDE in e-waste is expected to end up in recycled plastics. The same study shows that in the automotive sector, 14% of the POP-BDE is expected to end up in plastics recycling, while an additional 19% is expected to end up in second-hand parts (reuse) (IVM 2013). Furthermore, BDE-209 was detected in 100% of the isolation material and carpet padding tested and in 25 % of the plastic toys; both of these products were made from recycled plastics (IVM 2013). In the U.S. approximately 15-20% of post-use EEE was recycled and between 80 – 85% was disposed of in landfills or incinerated (U.S. EPA, 2007). The situation regarding the management of textile waste in both Europe and other regions is uncertain. The European Chemicals Agency (ECHA) however stipulates that c-decaBDE containing textiles are currently not recycled in the EU (ECHA, 2014a). There are uncertainties in the level of recycling of textile within parties and in terms of decaBDE content. Thus it is difficult to define whether a restriction on recycling of textiles containing decaBDE will have economic implications for the textile recycling industry.

49. At present around 20% of all plastic waste in the EU is recycled annually on average, of which only a smaller fraction is flame retarded plastic (RPA, 2014; ECHA, 2014a, EERA 2015). In the EU today 30 % of the WEEE contains FR and only some 5 % of the plastics fed into specialized plastics recycling plants for WEEE in average consist of plastics with BFRs (EERA 2015; ECHA, 2014a). In the U.S. EEE recycling is expected to increase in the future due to state law requirements, but in 2012 only 9 % of the total plastic waste generated was recovered for recycling (U.S. EPA, 2014a,c). For textiles, no or very limited material recycling takes place in the EU and in the U.S. (ECHA, 2014a; U.S. EPA, 2014a; RPA, 2014).

50. Available literature on BDE-209 levels in waste streams from Europe shows that BDE-209 levels are below detection limit in mixed plastics from mixed small household appliances (C2), small household appliances (P32) and mixed flat screen TVs (P42), while mixed plastics from CRT monitors (P31) and CTR TVs i.e. older computers and TVs may contain 3200 and 4400 ppm BDE-209 on average (Wager et al., 2011). A study of e-waste in Nigeria reported that BDE-209 was detected in 15 % (24 of 159) of the TVs tested. The concentration ranged from 0.086 to as much as 23.7 % with an average of 5.7 %. C-decaBDE was detected in 4.5 % of the tested PC CRTs (10 of 224). In computer monitors the concentrations ranged from 0.26- 5.4 %, average of 1.28 %.

51. Commercial PBDE mixtures c-pentaBDE (tetra- and pentaBDE) and c-octaBDE (hexa- and heptaBDE are listed in Annex A of the Convention with specific exemptions for recycling. To support Parties in the implementation of strategies to reduce the recycling of materials containing PBDEs, POPRC (Decision POPRC-6/2, UNEP/POPS/POPRC.6/2/Rev.1) outlined a series of recommendations that are relevant to c-decaBDE as well. In summary, POPRC recommended to eliminate PBDEs from the recycling streams as soon as possible. To meet this recommendation articles containing PBDEs should be separated from the waste stream before recycling. Failure to do so will inevitably result in wider human and environmental contamination and the dispersal of PBDEs into matrices from which recovery is not technically or economically feasible. Furthermore, PBDEs should not be diluted since this would not reduce the overall quantity in the environment.

52. In order to sort out c-decaBDE containing wastes for environmentally sound management and to avoid and/or minimize recycling of articles that contain c-decaBDE, effective screening and separation techniques are necessary for material containing FR. When screening and separation techniques are not readily available and concentrations are assumed to be above the low POP level, caution should be exercised and recycling avoided. Furthermore, waste, products and articles containing c-decaBDE should not be exported to developing countries since there is generally limited capacity or technology to treat the waste in an environmentally sound manner and protection of workers is limited or lacking.

53. Production and down-stream industrial use of c-decaBDE also contributes to the c-decaBDE emissions (UNEP/POPS/POPRC.10/10/Add.2). Although emissions in these stages of the life-cycle are generally assumed to be small (ECHA, 2014a), the environmental impact of industrial production and use can be high and likely depend on the technology used as well as management practices. The absence of decreasing trends in the environment following voluntary measures by the industry to reduce emissions during production and industrial use (ECHA, 2014a) suggests that that the emissions during service life and the waste stage are much higher than during production, and that a ban on production is necessary to fully eliminate c-decaBDE releases in these phases of its life-cycle as well as from articles in use.

54. A ban on the production and use of the BDE-209-component of c-decaBDE, together with waste management measures to reduce or eliminate releases from stockpiles and waste, including products and articles upon becoming wastes, would be an efficient way to eliminate all emissions of BDE-209 and can also considered as the most appropriate option for the phase-out of BDE-209 under the Stockholm Convention.

55. The alternative option would be to list the BDE-209-component of c-decaBDE in Annex A, B and/ or C with exemptions and/or acceptable uses. However, according to the Annex F information submitted by Parties, technically feasible alternatives appear to be available for all applications. However, already in October 2014, some industry observers have raised a concern regarding service and replacement of legacy spare parts in articles already in use and identified a possible need for exemptions in the transportation sector. The aviation and vehicle industry are in the process of phasing out c-decaBDE, and some materials and components could still contain c-decaBDE. The vehicle industry represented by ACEA has already indicated to globally phase out c-deca-BDE by the middle of 2018 for current production and new developments. Thus, an exemption is only required for some legacy spare parts with functional properties. In addition, a small number of Parties have suggested the possibility of a need for a recycling exemption in line with what has been agreed for previously listed POP-BDEs. Other parties oppose a recycling exemption due to lack of capacity to identify and analyse products containing deca BDE.

2.3 Information on alternatives (products and processes) where relevant

56. The U.S. EPA and ECHA recently published comprehensive assessments of chemical alternatives to c-decaBDE (U.S. EPA, 2014a; ECHA, 2014a). The U.S. EPA assessment provides detailed human health and ecological hazard information for 29 substances and mixtures that have been identified as potentially alternatives to c-decaBDE in a variety of applications (see Table 4, UNEP/POPS/POPRC.11/INF/6). The report published by ECHA identified 13 chemicals for further assessment and evaluation as alternatives to c-decaBDE (ECHA, 2014a; see Table 5, UNEP/POPS/POPRC.11/INF/6). Other assessments of alternatives to c-decaBDE have also been conducted in the past (LSCP, 2005; Illinois, 2006; CPA 2007; DME, 2007; ECB, 2007; Washington, 2008; Maine, 2010; ENFIRO, 2013).The research project, ENFIRO, assessed substitution options for selected BFRs by comparing information on hazard and by testing fire-and application performance for different uses.

57. To date, most assessments of alternatives to c-decaBDE/BDE-209 have focused on the replacement of c-decaBDE with alternative chemicals (i.e. a chemical that have flame retardant properties that can be substituted directly for c-decaBDE in articles). However, alternative techniques to improve fire safety also exist and are also described in some of the assessments (ECHA, 2014a; U.S. EPA, 2014a).

58. An overview over the available c-decaBDE alternatives is provided in Sections 2.3.2-2.3.5 below and UNEP/POPS/POPRC.11/INF/6.

59. Presented below (Table 3) are the categories of materials and sectors/products in which c-decaBDE has been or is currently used globally(see also further info in Tables 1, 6, 7 in UNEP/POPS/POPRC.11/INF/6).

Table 3
Summary of polymers where c-decaBDE is used as a FR and their end-use application by category

Polymer Group	End-Use Applications								
	Electronics	**Wire and Cable**	**Public Buildings**	**Construction Materials**	**Automotive**	**Aviation**	**Storage and Distribution Products**	**Textiles**	**Waterborne emulsions & coatings**
Polyolefins[1] (PE, PP, EVA)	x	x	x	x	x	x	x	x	x
Styrenics[2] (PS, HIPS, ABS)	x		x	x	x	x	x		
Engineering Thermoplastics[3] (Polyesters (PET, PBT), PA, PC, PC-ABS, PEE-HIPS)	x	x	x	x	x	x		x	x
Thermosets[4] (UPE, epoxies, melamine-based resins)	x		x	x	x	x	x	x	x
Elastomers[5] (EPDM rubber, thermoplastic PUR, EVA)	x	x	x	x	x	x	x	x	x
Waterborne emulsions and coatings[6]	x	x	x	x	x			x	x

Source: U.S. EPA, 2014a (Table 2.3.1)

[1] Polyolefins: polyethylene (PE), polypropylene (PP), ethylene vinyl acetate (EVA).
[2] Styrenics: polystyrene (PS), high-impact polystyrene (HIPS), acrylonitrile butadiene styrene (ABS).
[3] Engineering Thermoplastics: polyesters (polybutylene terepthalate (PBT), polyethylene terephthalate (PET)),polyamides (PA, nylons), polycarbonate (PC) and PC-ABS, polyphenylene ether- high-impact polystyrene (PE-HD), PE ether HIPS.
[4] Thermoset plastics: unsaturated polyesters (UPE), epoxies, melamine-based resins.
[5] Elastomers: ethylene propylene diene monomer rubber (EPDM rubber), thermoplastic polyurethanes (thermoplastic PUR), EVA.
[6] Waterborne emulsions and coatings: acrylic-, polyvinyl chloride (PVC)-, ethylene vinyl chloride- and urethane-emulsion.

2.3.1 Alternative substances

60. Different considerations are relevant when selecting a replacement for c-decaBDE. The Stockholm Convention Article 3 paragraph 3 requires Parties that have regulatory and assessment schemes for new chemicals to take measures to regulate with the aim of preventing the production and use of new chemicals that exhibit the characteristics of POPs. In addition, in accordance with Article 3 paragraph 4, Parties should take the POPs criteria in Annex D into account when conducting assessments of chemicals currently in use. According to the POPRC guidance on alternatives and substitutes, alternatives should moreover be available, accessible, efficient and technically feasible (UNEP/POPS/POPRC.5/10/Add.1). In addition, a replacement substance should ideally not substantially increase costs -neither costs of manufacturing or costs incurred as a result of harm to the environment and human health. For the downstream user, manufacturing costs may however not necessarily be the most critical point when substituting one chemical for another. For example, for engineering polymers, which are materials with exceptional mechanical properties, overall function is considered more important than price (KemI, 2005). Furthermore, in applications where chemical substitutes are being considered, an evaluation should first be conducted to address whether flame retardancy is needed and if so how appropriate fire safety can be achieved without adverse

environmental and human health consequences (ECHA 2014a). For example, and as discussed in chapter 2.3.5 below, in EEE, removing sources of ignition or reducing operative voltage requirements can eliminate the need for FRs (LCSP, 2005).

61. According to ECHA (2014a), the industry's choice of a new substitute chemical "will depend on when a possible further regulatory action is envisaged and the ease with which the alternative can be used to substitute c-decaBDE". In other words downstream users are assumed to be less likely to choose an alternative substance subject to current-or future regulatory risk management. They are also assumed to select a so called drop-in alternative i.e. an alternative substance with similar technical properties to the chemical already in use that can be phased in to the manufacturing process with minimal efforts. Nonetheless, substitution to an alternative chemical may necessitate additional changes in product formulation or movement to different classes of polymers, and product manufacturers transitioning to new FRs may have to test a number of chemicals or chemical combinations to determine if they meet performance requirements in final products (U.S. EPA, 2014a).

62. The hazard profiles generated by the U.S. EPA (U.S. EPA, 2014a; Table 4, UNEP/POPS/POPRC.11/INF/6) show that "some of the chemical alternatives have similar hazard profiles to c-decaBDE; other alternatives have trade-offs in hazard endpoints; some alternatives have preferable profiles compared to c-decaBDE. FRs with similar profiles are persistent, potentially bioaccumulative, and tend to have hazards for carcinogenicity, developmental neurotoxicity and repeated dose toxicity. Other alternatives are associated with the concern for hazard based on different endpoints, for example aquatic toxicity, and present hazard trade-offs when compared to c-decaBDE. The large polymers are anticipated to be safer because their large size limits bioavailability. Unfortunately, their long-term fate in the environment is unknown and halogenated polymers may generate halogenated dioxins and furans during combustion. Combustion by-products are not assessed in the report" (U.S. EPA, 2014a). Similar conclusions may be drawn based on the information on hazard and risk given in ECHA (2014a).

63. Among the different categories of chemical alternatives, BFRs would appear to be able to act as drop in replacements for a wide range of the known c-decaBDE applications (ECHA 2014a; U.S. EPA, 2014a). In addition, viable non-halogenated FR/polymer combinations have been identified as alternatives for most c-decaBDE uses. Some of the non-halogenated FR/polymer combinations may also have better performance than c-decaBDE/polymer (ENFIRO, 2013; see Table 8, UNEP/POPS/POPRC.11/INF/6).

64. From an industrial point of view i.e. a technical and economic perspective focused on manufacturing costs, decabromodiphenyl ethane (DBDPE) is identified as the most feasible replacement substance for c-decaBDE (ECHA 2014a). According to Environment Canada, DBDPE is a cost-effective replacement for c-decaBDE applications relevant to Canadian manufacturers, and a switch from c-decaBDE to DBDPE is said to be "likely ongoing" in USA and Canada (ECHA 2014a). DBDPE is also identified as the most likely substitute to c-decaBDE in the EU (ECHA, 2014a). However, U.S. EPA has identified DBDPE as "high hazard for developmental toxicity" and "a high hazard for bioaccumulation". These end-points were assigned using values from predictive models and/or professional judgement. The identification as "very high hazard for persistence" was based on empirical data (US EPA, 2014a). In addition, DBDPE is undergoing substance evaluation in the EU based on the concern that it may exhibit PBT/vPvB properties (ECHA 2014b, UK EA 2007). Other substances may also act as technically feasible reasonably priced alternatives for specific uses of c-decaBDE. Ethylene bis (tetrabromphthalamide) (EBTBP) is identified as another bromine-containing FR that can replace c-decaBDE in many of its applications (ECHA, 2014a). However, according to ECHA (2014a) which have compared the market price of c-decaBDE to that of its alternatives, information from the supply website Alibaba.com suggests that EBTBP is more expensive than both c-decaBDE and DBDPE. EBTBP may therefore be a less attractive alternative than DBDPE from a cost of manufacturing perspective. Nevertheless, one should keep in mind that the cost does not take into account the effectiveness of the alternative.

65. While alternative substances for replacing c-decaBDE in plastics, textiles and other uses are further discussed in sections 2.3.2- 2.3.4 below detailed information on the environmental- and health hazards of the c-decaBDE alternatives identified by the U.S. EPA (2014) is provided in Table 4,UNEP/POPS/POPRC.11/INF/6. Similarly, a detailed overview of the 13 alternative substances identified in the EU restriction proposal, their applicability for different uses, price, loading, environmental and health properties and economic feasibility is given in Table 5, UNEP/POPS/POPRC.11/INF/6 (for further details see also ECHA, 2014a). The viable non-halogenated FR/polymer combinations identified in the ENFIRO project are presented in Table 8,

UNEP/POPS/POPRC.11/INF/6, while other alternatives identified in the Annex F process are presented in Table 9, UNEP/POPS/POPRC.11/INF/6.

2.3.2 Plastics

66. The plastics industry is by far the major user of FR and the largest quantities of FR are supplied to raw-material manufacturers (KemI, 2005). The amount of c-decaBDE used in plastics and textiles globally varies but up to 90% of c-decaBDE ends up in plastic and electronics while the remaining ends up in coated textiles, upholstered furniture and mattresses (ECHA, 2014a; US EPA, 2014a). Like any other additives, a FR is selected by the raw material manufacturer for its inherent properties and compatibility with the polymer and to fulfil the specifications of the final product established by industrial customers (e.g. a car or furniture manufacturer). In the automotive sector this means that the specification of the end customer is only prescribing the performance requirements of the components. It is not precribing the material choise of the suppliers.

67. For c-decaBDE in plastics the largest down-stream uses are in EEE applications and include casings for EEE, wire and cable, and small electrical components (U.S. EPA, 2014a; see Table 1, UNEP/POPS/POPRC.11/INF/6). In the U.S., the main reported use was in the front and back panels of televisions made of high impact polystyrene (HIPS) (Levchick, 2010), but c-decaBDE was also used in electronic connectors made from glass-filled PBT or nylons. Other identified uses of c-decaBDE flame-retarded plastics are in buildings, construction materials, in storage and distribution products such as plastic pallets, in the transportation sector (cars, airplanes, trains and ships). Because of the restrictions on the use of c-decaBDE in EEE in important markets like Europe and China, many large electrical- and electronic companies have transitioned away from using c-decaBDE (KemI, 2005; U.S. EPA, 2014a). End-applications where c-decaBDE has been phased-out include front and back panels of televisions made of HIPS, electronic connectors made from glassed-filled polybutylene terephthalate (PBT) or nylons (Levchik, 2010 in U.S. EPA, 2014a). A ban on EE medical equipment entered into force in the EU on 22 July 2014. However, c-decaBDE flame retarded plastics are still used globally in a variety of EEE including household appliances and tools such as vacuum cleaners (in both the casings and internal components), and washing machines. In these appliances, the housings are typically made from polypropylene (PP), HIPS or ABS (U.S. EPA 2014a; Levchick, 2010). Another use that is still ongoing globally is in small electrical parts, such as light sockets or decorative lights and wires and cables which are usually made from high density polyethylene (PE), PP or polyphenylene (PPE) (U.S. EPA, 2014a; Levchick, 2010). Globally c-decaBDE is also still used in the plastics PBT and polyamides (PA), which are found in electrical, automotive, and plumbing parts such as housings, switches and other smaller internal parts of larger electrical equipment (Weil and Levchik 2009). For most plastic polymer applications where c-decaBDE is commonly used other FRs are available and already applied (KemI 2005).

68. The aviation industry still uses c-decaBDE in electrical wiring and cables, interior components, and EEE in older airplanes and spacecraft’s. In the transport sector, c-decaBDE continues to be used in plastics for EEE, reinforced plastics, under hood and in inner parts as well as in the interiors of cars. It is also used in other means of transportation (U.S. EPA, 2014a; see Table 1, UNEP/POPS/POPRC.11/INF/6). Most of the flame retarded plastics used in vehicles are found in the engine compartment (often polyamides). In addition, the firewall between the engine and the cabin is an important flame retarded part. However, it should be noted that in Europe fire-safety requirements for vehicles are not very strict and most of the automotive plastics are therefore not flame retarded (IVM/IVAM, 2013). Most global car manufacturers nonetheless follow the US Federal Motor Safety Standard (FMVSS) 302 for their global production. In addition, for omnibuses, fires safety measures acc. to the UNECE 118 have to be fulfilled in all UNECE countries.

69. C-decaBDE is reportedly still used in toys in China (Annex F China; Chen et al. 2009), and in the synthetic rubber industry as a FR in conveyor belts for use in mines, including underground coal mines, and in the manufacture of ventilation bands used as seals around air ducts in mine ventilation systems (Annex F Australia). Until recently, c-decaBDE was also used in plastic shipping pallets in the U.S. (U.S. EPA, 2014a), but the company producing these pallets is no longer in business (U.S. EPA, personal communication) and three U.S. states (Maine, Oregon and Vermont) have prohibited the manufacture, sale and distribution of shipping pallets containing c-decaBDE (Maine, 2008; Oregon, 2011; Vermont, 2013).

70. For plastics in EEE, substitution strategies range from exchange of the resin system and FR, to complete redesigns of the product itself. Alternative techniques such as redesign are further described in section 2.3.3 below. According to the EU restriction proposal, which assessed different alternatives to c-decaBDE, eight possible alternative chemicals appear to be possible substitutes for c-decaBDE in plastic polymers (ECHA, 2014a):

(a) Decabromodiphenyl ethane (DBDPE);

(b) Bisphenol A bis(diphenyl phosphate) (BDP/BAPP);

(c) Resorcinol bis(diphenylphosphate) (RDP);

(d) Ethylene bis(tetrabromophthalimide) (EBTBP);

(e) Magnesium hydroxide (MDH);

(f) Triphenyl phosphate (TPP);

(g) Aluminium trihydroxide (ATH);

(h) Red phosphorous.

71. In addition, one manufacturer has reported the availability of green fire retardant systems suitable as alternatives to c-decaBDE. An overview of plastic polymers containing c-decaBDE and the alternative FRs for these uses, including down-stream applications, is provided in Tables 5-9, UNEP/POPS/POPRC.11/INF/6.

72. Detailed information on uses/applications, loading, costs and hazard for the identified alternatives to c-decaBDE in plastics, is reported in Tables 5 and 9, UNEP/POPS/POPRC.11/INF/6. Typically c-decaBDE is used in plastics/polymers at loadings of 10-15% by weight, though in some cases loadings as high as 20% have been reported (ECHA, 2012c). According to the manufacturer, Paxymer ® has excellent, proven performance in PP and PE with addition levels ranging from 2-32% depending on the downstream application and use. Reported loadings and cost for other alternatives used in plastics range from 1-60% and 1-12 €/kg respectively (see Tables 5and 9, UNEP/POPS/POPRC.11/INF/6).

73. In certain uses, plastics have to fulfil fire safety regulatory requirements as mandatory specifications. Compliance with the fire requirements for plastics is controlled with well-defined flammability tests such as the International Electrotechnical Commission (IEC), or in the regulations and approval procedures of the Underwriters' Laboratories Inc. (UL), the latter mainly operating on the US market (KemI, 2005). However, although these fire regulations are mandatory for the market, there are no fire regulations that require the use of certain FRs in order to comply with these standards or regulations. Hence, it is up to the manufacturers to decide which technique to use. The ideal chemical FR for plastics should be compatible (i.e. not alter the mechanical properties of the plastic), not change the colour of the plastic, have good light stability, and be resistant towards ageing and hydrolysis. Further, an ideal chemical FR should match and begin its thermal behaviour before the thermal decomposition of the plastics, not cause corrosion, not have harmful physiological effects, and not emit or at least emit low levels of toxic gases. It should ideally also be as cheap as possible. However, as indicated earlier, function is generally more important than price for engineering polymers and price is not necessary the most important factor when selecting an alternative (KemI, 2005). As indicated above fire safety requirements for vehicles in Europe are not very stringent. Most global car manufacturers nonetheless follow the safety standard of the US Federal Motor Safety Standard (FMVSS) 302 for their global production. In addition, for omnibuses, fires safety measures acc. to the UNECE 118 have to be fulfilled in all UNECE countries.

74. In summary, efficient and technically feasible alternatives to the use of c-decaBDE as a FR in plastics (and synthetic rubber) are available and accessible on the market (ECHA, 2014a). DBDPE may be the most likely drop-in substitute for c-decaBDE in most plastics, but other alternatives or non-chemical techniques may offer a more sustainable long-term alternative to c-decaBDE than DBDPE (ECHA, 2014a).

2.3.3 Textiles

75. C-decaBDE has traditionally been applied to textiles as a back-coating in combination with antimony oxide (ATO) as a synergist (LCSP, 2005). Halogen-ATO can only be applied topically in a resin binder. C-decaBDE is first mixed with ATO to form an aqueous dispersion, which is then mixed with a polymer emulsion containing e.g. natural or synthetic rubber, EVA, styrene-butadiene copolymer or PVC (ECHA, 2012c). The c-decaBDE/ATO FR mix can account for 18 to 27% of the total weight of the product (Washington, 2006). Lighter fabrics usually require higher FR loadings than heavier fabrics. Fire resistant back-coatings are effective on a wide range of fabrics, including polyamide/nylon, polypropylene, acrylics, and blends such as nylon–polyester.

76. In the U.S. c-decaBDE is used in textile applications for transportation (public transit buses, trains, aviation and ships), in draperies for use in public occupational spaces, in furniture of high-risk occupational areas such as nursing homes, hospitals, prison and hotels, and in military for tarps, tents

and protective clothing, but are not used in consumer clothing (LCSP 2005; BSEF 2007 as cited in U.S. EPA, 2014a). However, in several U.S. states the use of c-decaBDE in residential upholstery and mattresses is no longer allowed (LCSP, 2015). In the EU, c-decaBDE is also used in domestic draperies and furniture (in foams, fillings and back-coatings, predominantly in countries with certain fire safety standards such as the UK (ECHA, 2014a). In Japan, vehicle seats accounts for 60% of the c-decaBDE use while an additional 15 % is reportedly used for other textile applications (Sakai et al., 2006). According to U.S. furniture industry sources in 99% of cases, chemical FRs will not be needed to meet pending national standards for residential upholstery (Illinois, 2007; Maine, 2007a). The same may be true in Europe. When testing 320 combinations of 20 cover fabrics and 18 fillings of upholstered furniture for the EU market, 38% of the combinations without FRs passed both match and cigarette test, and in the group that passed only cigarette test the FR-free combination accounted for 62% (CBUF as cited in Guillaume et al., 2008).

77. The lack of labelling, and information on FR use in consumer products makes it difficult to assess human exposure sources. Various eco- or green-labelling certifications may indicate that the product is FR-free. However, FRs are still widely used in furniture. For example, in a study analysing 102 polyurethane foam samples from residential couches purchased in U.S from 1985 to 2010, FRs were detected in 85% of the samples. For sofas purchased after 2005, tris (1,3-dichloroisopropyl) phosphate (TDCPP) was detected in 52%, and components associated with the Firemaster550 mixture were detected in 18% of the samples. In addition, a mixture of non-halogenated organophosphate FRs were observed in 13% of the samples (Stapleton et al., 2012). The textile covering the foam, which is where c-decaBDE could be expected was not analysed in this study.

78. Substitution of c-decaBDE in textiles is not straight forward due to the complexity of the end-products and the wide array of possible substitution approaches. These approaches include substitute FRs, alternative fibres, inherently fire resistant fibres, barrier layers, and nonwovens. However, a number of affordable options are available to replace c-decaBDE uses in furniture, mattresses, draperies and other textile applications. Substitution options for textiles range from brominated additive FRs such as DBDPE, to alternative techniques and inherent flame-resistant materials, which are described in Section 2.3.3 of the present document.

79. Based on its technical compatibility with existing processes and its price compared to c-decaBDE several European industry stakeholders have confirmed that DBDPE would be the preferred alternative to c-decaBDE in textiles (ECHA, 2014a; RPA, 2014; Klif, 2008). However, a focus on “drop-in” solutions may limit the innovative thinking that is needed to find effective and environmentally sound solutions (LCSP, 2009).

80. Some c-decaBDE substitutes exist for synthetics, but their water solubility results in limited durability as they “wash out” during laundering. Natural fibres are easier to chemically flame retard than synthetics, and there are several chemical non-halogen c-decaBDE substitutes available for natural cellulose or protein fibres such as cotton, wool, rayon (viscose, modal and lyocell), and linen. They include:

(a) Ammonium polyphosphates;

(b) Dimethylphosphono (N-methylol) propionamide;

(c) Phosphonic acids such as (3-{[hydroxymethyl]amino}-3-oxopropyl)-dimethyl ester;

(d) Tetrakis (hydroxymethyl) phosphonium urea ammonium salt.

81. Co-polymerization refers to inclusion of an additive in the fibre melt spinning process which makes the FR a physically part of the fibre matrix. The most common FR for polyester is polyethylene terephthalate with built-in phosphorus on the polyester backbone. This modified polyester is used in the majority of textile applications, is wash resistant, and is thought to be a good substitute for the c-decaBDE/antimony flame retardant. Polyester accounts for 30% of the world fibre production (see Figure 1, UNEP/POPS/POPRC.11/INF/6). Applications include clothing and draperies. Draperies that employ inherently flame resistant polyester can be laundered in water since the phosphate FRs are part of the polymer backbone and are not water soluble (LCSP, 2005).

82. Both ECHA (2014a) and U.S. EPA (2014a) have considered risk-hazard information on the identified alternatives. While there is no single replacement for c-decaBDE for textiles applications (Table 11 and 12, UNEP/POPS/POPRC.11/INF/6), the multitude of options on the market make it clear that viable approaches exist (LCSP, 2005). The identification of several halogenated and non-halogenated FRs in a study of chemicals commonly used in textile strengthen this (KemI, 2014, see Table 13, UNEP/POPS/POPRC.11/INF/6). The following seven substances were identified as the most likely chemical alternatives to the use of c-decaBDE in textiles (ECHA, 2014a):

(a) Aluminum trihydroxide (ATH);

(b) Magnesium hydroxide (MDH);

(c) Tris(1,3-dichloro-2-propyl) phosphate (TDCPP);

(d) Ethylene bis(tetrabromophthalimide) (EBTBP);

(e) 2,2'-oxybis[5,5-dimethyl-1,3,2-dioxaphosphorinane] 2,2'-disulphide;

(f) Tetrabromobisphenol A bis (2,3-dibromopropyl ether) (TBBPA) (only in polymer applications);

(g) Red phosphorous;

(h) Decabromodiphenyl ethane (DBDPE).

2.3.4 Other uses

83. In addition to the use in textiles and plastics c-decaBDE is used in sealants, adhesives, architectural foam, and coatings as well as in some applications in buildings and construction. C-decaBDE is used in wall and roof panels, which are typically made from unsaturated polyester (UPE) glass composites; floor tiles; and commercial grade carpeting. C-decaBDE is also used in e.g. in insulation materials, and in roofing materials such as membranes and films for use under roofs to protect building areas (Table 1, UNEP/POPS/POPRC.11/INF/6). C-decaBDE can also be found in ducting elements such as the duct covering or insulation. The EU restriction proposal for c-decaBDE identified the following six chemicals as alternative substances for these applications:

(a) Magnesium hydroxide (MDH);

(b) Aluminum trihydroxide (ATH);

(c) Ethylene bis(tetrabromophtalimide) (EBTBP);

(d) Substituted amine phosphate mixture (P/N intumescent systems);

(e) Red phosphorous

(f) Decabromodiphenyl ethane (DBDPE).

2.3.5 Alternative techniques and inherent flame-resistant materials

84. Alternatives that eliminate the need for chemical FRs through material substitution or design while meeting relevant fire safety standards and performance requirements are preferable, especially when they include chemicals of low toxicity and contain recyclable or compostable materials (New York State, 2013). The assessments of technical and economic feasibility of alternatives to c-decaBDE are primarily focused on alternative chemicals that directly can substitute c-decaBDE in articles (Section 2.3.2 above). However, flame retardancy can be achieved through the use of alternative techniques such as inherent flame-resistant material, use of different technical solutions i.e. barriers or complete redesign of the product. For example, power supplies can be shielded with metal to eliminate FRs or even be removed from the product as has been done with printers and rechargeable phones (LCSP, 2005). Inherent flame-resistant materials can meet fire code standards without special processing or chemical additives. Furthermore, the protection is incorporated into the fibres and is less likely to be worn away or washed out (DuPont, 2010). The mentioned alternative techniques can be used in a multitude of materials and applications, and are used in textiles, electronics, aircraft, and ground transportation vehicles and may be used in place of c-decaBDE in some instances. Examples of different alternative techniques, their attributes, and end-use products relevant to this assessment are given in Tables 14 and 15, UNEP/POPS/POPRC.11/INF/6.

Plastics

85. An alternative to the use of chemical FRs is redesign of the product itself. Redesign has successfully replaced c-decaBDE in several EEE applications. Redesigns of the product such as (i) separating high-voltage components that need greater ignition protection from low-voltage components and (ii) reducing operating voltage requirements and therefore reducing the need for flame-retarded enclosure materials.

86. Another product redesign alternative is to remove the power supply from the product. This is common in many devices including printers and rechargeable phones. These separate power supplies are typically black boxes connected to the power cord but not included in the unit itself. The separate power supply reduces the fire retardancy requirements of the electronic enclosure. To change product designs and their implementation would require a higher level of research and development activities

than the substitution of c-decaBDE with an alternative chemical FR but may be more sustainable as a long-term alternative.

87. Metal or inherently flame-resistant plastic can be used as alternative materials in certain electronic products. Options that eliminate the need for FRs through material substitution while meeting fire safety standards and performance specifications are considered preferable, particularly when product materials are derived from chemicals of lower toxicity and the products and/or materials are able to be recycled or composted (CPA, 2015). Material substitution that eliminates/reduce the need for chemical FRs has been shown possible by Apple Inc., which phased out BFRs (including c-decaBDE) in many of its computer products such as laptops, computer monitors, central processing units and servers (Apple Inc.). Apple Inc. replaced electronic encasements previously made of polycarbonate with encasements made of aluminium alloy, thereby eliminating the need to use FRs (Apple Inc.). A number of international producers of electronic equipment (Ericsson Network Technologies, Electrolux, IBM, Atlas Copco, Sony Ericsson, and Hewlett Packard) reported that they have phased-out- or never used c-decaBDE in their products (KemI, 2005).

88. Introduction of flame resistant metal barriers that separate or isolate the most flammable parts from the rest of the product and eliminates the need for FRs such as c-decaBDE has also been shown (LCSP, 2005).

89. In the EU assessment (ECHA, 2014a) various alternative techniques that could be used to replace c-decaBDE as a FR in plastics were identified. These include intumescent systems, nanocomposites, expandable graphite, smoke suppressants, polymer blends, use of inherently flame retardant materials and product redesign. These alternatives techniques are described in detail in Table 14 of UNEP/POPS/POPRC.11/INF/6. Another option is layering where an article is produced using layers of highly FR filled polymer and low or non-flame retarded polymer. This apparently gives a similar level of fire performance as would be achieved if the entire polymer had been treated, while helping to retain the mechanical properties of the polymer (ECHA, 2012c).

90. The use of inherently flame retardant materials is an additional alternative technique that can be considered. Halogenated polymers such as PVC have FR properties because they release halogen radicals during combustion. The effect is often enhanced by the addition of synergists such as ATO to halogenated polymer blends. However, like BFRs may PVC form dioxins and acids upon combustion and are therefore not a preferred alternative FR material (Blomqvist et al., 2007a). The following are polymer materials that are inherently flame-retardant and which might be considered as a substitute to c-decaBDE-based polymers like poly(butylene terephthalate) (PBTE) or polyamide/ nylon (PA) (DME, 2006):

(a) Halogen-free polyketone (this is considerably more costly than PBTE and PA);

(b) High performance thermoplastics such as polysulphone, polyaryletherketone (PAEK) or polyethersulphone (PES).

91. For certain uses, inherently flame retardant materials can include re-design solutions using metal enclosures and others. Polymers that char such as polyimides, polyaramides, liquid crystal polyesters, polyphenylene sulphide, polyarylenes and many thermosets also tend to have a greater resistance to fire. Where the base polymer has FR properties, depending on the end use, a sufficient level of fire performance may be achieved without the need for chemical FRs or much lower loadings may be required (ECHA, 2012c).

92. Some examples of new inherently flame retarded materials are mentioned in literature or in commercial websites, and these are often promoted as replacements for c-decaBDE (ECHA, 2012c; Albemarle, 2013; Great Lakes, 2013; PR Newswire, 2010). It may be necessary to change product designs to adopt these alternative materials and their implementation would require higher level of research and development activities than the substitution of c-decaBDE with a FR drop in chemical replacement. However, a safer environmental and public health profiles are additional benefits.

Textiles

93. An alternative approach to achieve flame retardancy in furniture is redesign of products to incorporate non-flammable materials or barrier technologies (LCSP, 2005). Product design choices can successfully meet all current and pending fire safety standards. Two approaches are suitable: 1) use of cover fabrics made from materials that are inherently fire resistant, 2) use of fire-resistant barriers between the cover fabric and the flammable cushioning foam.

94. There is a tremendous variation in the flame resistance of various fibres and fabrics. FR use in textiles can be avoided if the material itself is non-flammable or has low flammability. A number of synthetic fibres are inherently flame resistant, including aramid, viscose, novoloid, polyamides, and

melamine. Some of these fibres are starting to be significantly used in furniture upholstery and mattresses. Traditionally, they have been used to meet the strictest standards for applications such as fire fighter turnout gear, clothing for astronauts, and clothing for race car drivers. Inherently flame resistant fibres like polyhaloalkenes contain halogens such as polyvinyl chloride and vinyl bromide, while others are halogen free, including polyaramides and melamine fibres (LCSP, 2005; see Table 10, UNEP/POPS/POPRC.11/INF/6). Other inherently flame-retarded materials include rayon with a phosphorus additive, polyester fibres, and aramids (Weil and Levchik, 2009). Furthermore, some natural materials like leather and wool have inherently fire-resistant properties. Depending on the tightness of the weave, they can meet fire safety requirements without any additional FR treatment. Some natural materials such as wool may therefore be used as barrier materials in furniture (Klif, 2011).

95. Blending natural and synthetic fibres is another approach since the natural fibres are more effectively flame retarded. Fibre blending is a common method of reducing the flammability of flammable fibres. Polyester is usually blended with cotton and this ‘poly-cotton’blend, can pass the simple vertical strip flammability test, if it has lower than 50% polyester content. Furthermore, cotton-nylon blends are commonly used to reduce the flammability of cotton (Gnosys et al., 2010) as well as cotton or polyester blended with melamine. Some fabrics for upholstery, mattresses and drapery are made from blends of several inherently fire resistant fibres mixed with fibres of lower flame performance. In some cases, fibres with a better “feel” such as cotton or polyester can be combined with more flame resistant fibres, such as melamine, to form a fabric that performs well in both comfort and fire performance (LCSP, 2005).

96. An important aspect of furniture and mattress fire protection is the use of barriers between the surface fabric and the interior foam core. In mattresses, industry has made a shift and fire resistant barriers are now commonly used (Maine 2007b; IKEA 2014). Fire barriers are made from inherently flame-retarded fibres such as wool, para aramids, melamines, modacrylics, or glass fibre, and do not rely on the use of flame retardant chemicals. Moreover, many of these fibres are made from non-halogen materials. Some barriers can also be made of blends of inexpensive fibres and expensive inherently fire-resistant fibres. These barriers protect the mattress, futon or box spring core material from combustion. They fully encapsulate the interior materials and must be combined with fire-resistant border seams, tape, and threads (LCSP 2005). In addition to the use of fibre blends, many manufacturers use cotton-batting materials treated with boric acid. These cotton materials are the lowest-cost barrier technology and are used to help meet fire safety requirements. However, the use of boric acid is of concern since it is suspected to be a human reproductive toxicant. Animal studies have reported adverse effects on reproduction in rats and mice exposed to dietary boric acid prior to- and during mating (Weir and Fisher 1972; NTP 1990 as stated in New York State Department of Health 2013). Plastic films have also been used as barriers, especially films made of inherently flame-resistant plastics such as neoprene (polychloroprene) (LCSP, 2005).

97. In textiles, like in plastics, fire safety may also be achieved by the use of intumescent systems (Klif, 2011; U.S. EPA, 2014a). 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 and 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 (Klif, 2011). Intumescent systems may not be applicable to the same sets of textiles as BFR-based back-coatings.

2.3.6 Fire-safety standards, requirements and solutions

98. Society needs systems to reduce and prevent fires and protect human lives. Fires cause injury, deaths and destruction of properties worldwide every year. On the other hand, in countries with stringent fire safety regulations the use of some FRs and resulting environmental contamination and human body burden is reportedly higher than in other countries with more flexible regulations for the fulfilment of the fire requirements (Klif, 2011). This indicates that awareness about these issues is important when seeking to replace hazardous FRs.

99. A study comparing fire statistics from Europe, the USA and New Zealand concluded that smoking and cooking, in combination with the presence of upholstered furniture and textile, are the most common cause and accident pattern in fatal domestic fires (NIFV, 2009). Men, children and

elderly are the most frequent victims, and alcohol use is another major aspect of fatal domestic fires. Most fatal fires occur in the living room or bedroom at night during the weekend and involves (upholstered) furniture, textiles, technical appliances or clothing. In Europe, upholstered furniture played an important role in almost 50% of all fatalities in domestic fires, and in USA upholstered furniture first ignited in 18% of home fire deaths (ACFSE, 2001; NFPA, 2013). Polyurethane foam from upholstered furniture is a major contributor to increased toxic smoke (Molyneux et al., 2014; Stec et al., 2011). Statistics from Norway indicate that 23% of all the domestic fires start in the kitchen while 19 and 9 % start in the living room and bedroom, respectively containing upholstered furniture (NFPA, 2014).

100. The fire performance of a material or product is mainly tested for ignitability, ease of extinguishment, rate of flame spread, rate of heat release and smoke formation (Weil and Levchik 2009). The fire requirements of products are often dependent on the intended use (e.g. higher requirements for institutional buildings compared to domestic houses). Typically, fire regulations prescribe the use of verified technical standards developed by standardisation organisations such as ISO, International Electrotechnical Commission (IEC) or European Committee for Standardization (CEN) and safety consulting and certification companies such as the Underwriters' Laboratory INC (UL). However, neither national fire-safety regulations nor technical standards require use of specific FR chemicals to meet fire safety requirements. Furthermore, performance of products in these test standards does not always correlate to performance in a practical fire situation. UK, Ireland and California previously relied on open flame tests for upholstered furniture, which led to a higher use of BFRs and increased body burdens (UNEP/POPS/POPRC.10/10/Add.2, UNEP/POPS/POPRC.10/INF/5). The test guidelines for the UK regulation are now under revision. A possible change from the current "match- and cigarette test" that requires fabric covers to be tested over non-combustion-modified polyurethane foam, to tests that require the actual final composite to be assessed for fire performance (DBIS 2014). DBIS believes this will give a reduction of up to 50% of FR currently used. Californian furniture flammability standards have been changed such that future use of FRs can be excluded (TB117-2013).

101. FRs can temporarily slow the spread of fires and subsequent heat release for a short time in order to enable people to escape, but they may also increase the toxicity of emissions. Toxic emissions may be reduced by introducing a barrier material in combination with the FR. Fire toxicity is the largest cause of death and injury in fires but is usually not taken into account by regulators. Several toxic gases are produced during fire, some of which are linked to the presence of BFRs while others are not. Combustion of materials containing halogenated FRs during accidental fires and burning flame-retarded waste can increase the toxicity of fire effluents by increasing the release of CO, acid gases such as hydrogen bromide, and brominated and chlorinated dioxins and furans (Simonson et al., 2000; Blomqvist et al., 2007b, Shaw et al., 2010). Furthermore, studies indicate that BFRs in combination with antimony produce high yields of CO and HCN, two main asphyxiants in fires (Molyneux et al., 2014; Stec et al., 2011). 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. In line with these findings, the overall fire safety benefit of using these substances to fulfil fire safety requirements has been questioned by a group of scientists (Jayakody et al., 2000; DiGangi et al., 2010).

102. In domestic and institutional buildings, fire safety can be strengthened by yearly educational campaigns focusing on safe use of electric components, candles, fireplaces, stoves, and new generation smoke detectors etc. Requirements of easy access to escape routes and fire-fighting equipment such as fire hose, automatic sprinklers, fire extinguishers and fire-blankets are important measures to prevent and reduce loss from fires and to ease the escape from burning buildings. A further safety solution include the "reduced ignition propensity" (RIP) cigarettes which are meant to be self-extinguishing when left unattended. This has apparently reduced cigarette fire fatalities by 41% in New York State. This is now mandatory in all the U.S., Canada, Australia and the EU. Solutions for electrical products could include a built-in heat sensor that shuts off the object if it becomes too warm. Regular control and changing of electrical wiring system are also fire preventive.

103. During storage e.g. in warehouses, fire safety can be strengthened by management practices. According to Annex F information from IPEN, fire safety when using plastic pallets may be met without FRs by implementing systems such as pallet storage management practices (e.g. how high the pallets are stacked and how close together stacks of pallets are) and/or by using sprinkler systems.

104. According to information provided by the aviation industry, aerospace products are subject to stringent airworthiness regulations and certification specification which set performance standards, including flammability. An overview of the process is described in Section 2.1 of ECHA, 2014). These fire resistance- and safety requirements are intended to prevent and/or control fires both in

flights, where options for escape are limited and post-crash, where evacuation from fuel-fed fires is the primary concern. These drive the choice of substances to be used. Aircraft parts and components are expected to withstand fire for a specified time depending on the area and application and materials used in interiors must not generate toxic smoke or excessive heat when on fire. For these reasons materials such as FRs is applied in hot and fire sensitive areas (e.g., around engines). Airworthiness authorities such as the European Aviation Safety Agency (EASA), Civil Aviation Administration of China (CAAC), Transport Canada Civil Aviation (TCCA), Agência Nacional de Aviação Civil (ANAC), Australian Civil Aviation Safety Authority (CASA), and U.S. Federal Aviation Administration (FAA) are responsible for establishing, administrating and enforcing flammability standards.[2] These flammability standards for the aviation sector have been demonstrated to significantly reduce the probability of death from fire in a survivable accident by a factor of three over the past 40 years (FAA, 2010) (Boeing Company, pers. comm.).

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

105. A positive impact on human health and the environment can be expected from a global reduction or elimination of c-decaBDE. POPRC-10 concluded that BDE-209, the main constituent of c-decaBDE, at present exposure and effect levels are likely to lead to significant adverse human health and environmental effects as a result of its long-range environmental transport such that global action is warranted (UNEP/POPS/POPRC.10/10/Add.2).

2.4.1 Health, including public, environmental and occupational health

106. BDE-209 is widely detected in the global environment and some species have high body burdens, in particular some species of birds, but also otter and fox living in urban and suburban areas (UNEP/POPS/POPRC.10/10/Add.2). Furthermore, in some organisms such as frogs, fish and birds BDE-209 levels are close to or within the range of reported effect concentrations for developmental-, neurotoxic- and endocrine disruptive effects. BDE-209 concentrations in Arctic cod, a key species of Arctic ecosystems, were reported to be at a level that can lead to adverse effects, which in turn can have a negative impact on Arctic cod populations and the whole Arctic ecosystem. Adding to this concern is the potential for low-dose and combined effects between BDE-209 and other similarly acting PBDEs as well as the potential for multiple stressor effects (UNEP/POPS/POPRC.10/10/Add.2, UNEP/POPS/POPRC.7/INF/16). A positive impact of imposing control measures is a decrease in emissions, which over time will reduce exposure and bioaccumulation in humans and wildlife. A global ban or restriction of c-decaBDE is therefore a measure that will contribute to protect and preserve Arctic organisms and ecosystems, which are considered to be at particular risk from POPs (AMAP 2009; UNEP/POPS/POPRC.7/INF/16).

107. Within a short time period, the most positive effect of imposing global control measures would possibly be on the indoor environment and public health; with c-decaBDE levels in dust being reduced and ultimately eliminated by ending the use in indoor textiles and equipment. Imposing control measures would also ensure that levels in agricultural products like milk/milk products, various meat products and fish decrease over time. In humans, exposure to BDE-209 takes place already in the early phases of human development and continues throughout life. It is found in human blood, plasma, breast milk and it is transferred to the foetus via the placenta during critical stages of development. The main sources for human exposure presently known are dust and contaminated food (UNEP/POPS/POPRC.10/10/Add.2). Due to their hand-to-mouth behaviour, infants and toddlers have higher body burdens of BDE-209 and other PBDEs than adults and have been identified as vulnerable groups that could be at risk, particularly due to the neuroendocrine and neurodevelopmental toxicity

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[2] Examples of civil flammability standards:

EASA (e.g., CS 25.853, Appendix F) – https://www.easa.europa.eu/system/files/dfu/CS-25%20Amdendment%2016.pdf

CAAC (e.g., 第25.853 条, 附录F) – http://www.caac.gov.cn/B1/B6/201112/P020111209503321901800.pdf

TCCA (e.g. 525.853, Appendix F) –

https://www.tc.gc.ca/eng/acts-regulations/regulations-sor96-433.htm#v

ANAC (references US 14 CFR 25)

http://www2.anac.gov.br/biblioteca/rbac/RBAC25EMD136.pdf

CASA – (e,g., Part 90 Subdivision 3.2, references 14 CFR 25.853) – http://www.comlaw.gov.au/Details/F2011C00871/Html/Text#_Toc306971168

FAA (e.g., §25.853, Appendix F) –

http://www.ecfr.gov/cgi-bin/text-idx?tpl=/ecfrbrowse/Title14/14cfr25_main_02.tpl observed in animal studies (UNEP/POPS/POPRC.10/10/Add.2). Eliminating or restricting the use of c-decaBDE will therefore be particularly beneficial for the developing child.

108. Eliminating or restricting the use of c-decaBDE will also lead to better protection of worker health, particularly in developing countries where personal protection equipment is limited, and will also reduce human and environmental exposure to toxic degradation products including lower brominated PBDEs, brominated dioxins and furans (PBDD/PBDF), pentabromophenol and hexabromobenzene. Toxic degradation products, including PBDD/Fs may be formed different ways; during thermal processing (extrusion, molding and recycling), plastics production, photolysis, food preparation (cooking of fish) and waste disposal (Vetteret al., 2012; Kajiwara et al., 2008, 2013a,b; Hamm et al., 2001; Ebert and Bahadir 2003; Weber and Kuch 2003; Thoma and Hutzinger 1987; Christiansson et al.,2009; UNEP/POPS/POPRC.6/INF/6). Regarding occupational exposure, elevated BDE-209 levels have been reported in a number of professions (UNEP/POPS/POPRC.10/10/Add.2). Moreover, a study of 12 firefighters in the U.S. showed that they had elevated BDE-209 concentrations in their blood (contributing >50% of total PBDE concentration in serum) as well as elevated amounts of PBDD/Fs (Shaw et al., 2013). The authors of the study “suggested that PBDD/Fs may contribute substantially to dioxin-like toxicity in individual firefighters”, and that occupational exposure to these compounds during firefighting is significant. Thus, the exposure is likely to contribute to adverse health outcomes, an assumption underpinned by data also from other studies were firefighters are known to have elevated rates of cancer including four types that are potentially related to exposure to PCDD/Fssuch as multiple myeloma, non-Hodgkin’s lymphoma, prostate, and testicular cancer (Hansen et al., 1990; IARC 2010; Le Masters et al., 2006; Kang et al., 2008). On the other hand studies suggest that when appropriate measures are in place, such as personal protection equipment and a ventilation system, exposure can be significantly reduced. A recent study showed that by applying appropriate risk management measures in a Swedish electronics recycling facility BDE-209 does not pose a risk to worker’s health (Rosenberg et al., 2011; Thuresson et al., 2006). However, worker’s in developing countries and countries with economies in transition are likely to be more exposed to BDE-209 and other substances than workers in developed countries because risk reduction measures are typically not in place or not fully enforced (Tsydenova and Bengtsson, 2011; UNEP/POPS/POPRC.10/10/Add.2; ILO 2012).

109. BDE-209 levels are generally highest near wastewater discharges and in areas around electronic waste and recycling plants (UNEP/POPS/POPRC.10/10/Add.2). Environmentally sound management of waste is therefore important in order to achieve an adequate level of protection of human health and the environment. This is in particular important in developing countries where waste handling often occurs under conditions without the use of modern industrial processes, and where worker protection is often inadequate. Considering the wide use of c-decaBDE in EEE, and that e-waste is the world's fastest growing waste stream (StEP, 2013) EEE in use and upon becoming waste are of particular concern. Last year nearly 50 million tonnes of e-waste were generated worldwide, about 7 kg for every person on the planet. Furthermore, millions of tonnes of old electronic goods are exported to developing countries and countries with economies in transition, primarily to South-East Asia, and to an increasing degree West Africa and Eastern Europe. Increasingly, Senegal, Uganda, Morocco, Colombia, Peru, Kenya, South Africa, Cambodia and Iraq are also destinations for end of life products and articles (Ni and Zeng, 2009; Zoeteman et al., 2010; Schluep et al., 2009 in ILO 2012). Treatment in these countries usually occurs in the informal sector, causing significant environmental pollution and health risks for local populations. Women and children constitute a significant proportion of the workforce (ILO 2012). In China, which today receives the highest proportion of all e-waste globally, levels of BDE-209 in soil at e-waste sites and recycling plants are very high (ILO 2012; Wang et al., 2010, 2011a,b, 2014; Gao et al., 2011, Li et al., 2013). In addition to the occupationally exposed dismantlers, people residing near production and recycling facilities also have elevated blood levels of BDE-209 (see UNEP/POPS/POPRC.10/10/Add.2). In Bangladesh and Nicaragua, children living and working at a waste disposal sites have a combination of BDE-209 and other hazardous chemicals in their blood (Linderholm et al., 2011; Athanasiadou et al., 2008). Open burning of e-waste containing PBDEs is moreover estimated to release tons of PBDD/Fs and PCDD/Fs into the environment (Zennegg et al., 2009). Ma et al., (2009) reported that TEQ PBDD/F concentrations from an e-waste recycling facility in China exceeded the TEQPCDD/F concentrations in environmental samples. Moreover, c-deca BDE-containing plastic e-waste also find their way to food contact articles made from recycled plastics where it contributes to human exposure and risk (Samsonek and Puype 2013; Puype et al., 2015). Although recycling of materials that do not contain hazardous chemicals is environmentally and economically beneficial, recycling of materials containing POPs and other hazardous chemicals should be avoided to protect human health and the environment. Avoiding recycling of POP-containing materials also lowers the risk that contaminated materials is exported to developing countries. Avoiding recycling of POP-containing materials is also important to protect the credibility

of recycling, stimulate to sustainable management of waste flows and increase innovation in the recycling industry as well as other industries. Negative aspects of not allowing such recycling could on the other hand include loss in material being recycled (resources), additional costs to recycling companies due to separation/dismantling efforts and increased use of virgin materials (resources) (UNEP/POPS/POPRC.6/2/Rev.1). With regards to the challenges faced by developing countries due to e-waste ILO (2012) highlights the complexity of illegal transport of e-waste and proposes several solutions, amongst others that effective regulation and enforcement must be combined with incentives for recyclers in the informal sector not to engage in destructive processes and formalization of the informal e-waste recycling sector. Others suggest that proper law enforcement and international collaboration are keys in solving the problem of illegal transports (Ni and Zeng, 2009). The available literature suggests different approaches to e-waste management and recycling (e.g. Bleher et al. 2014, UNEP 2012, UNEP/POPS/POPRC.6/2/Rev.1). Some of the suggested approaches which include 1) not-allowing recycling of POP-containing waste, 2) recycling of non-BFR plastics and incineration of POP-contaminated plastics combined with energy recovery and 3) recycling of all plastics including BFR plastics below a legally determined threshold level are compliant with the objectives of the Stockholm Convention and should be feasible also for developing countries. The different approaches differ in how they handle the FR/ c-decaBDE containing fraction and the economic gain for the industry (Bleher et al. 2014).

2.4.2 Agriculture, including aquaculture and forestry

110. Elimination of c-decaBDE would benefit agriculture as well as human and wildlife health by ending further widespread dispersal of a POP substance to soil. Contamination of agricultural soil with BDE-209 is a global problem partly linked to the use of sewage sludge as a fertilizer (UNEP/POPS/POPRC.10/10/Add.2). As shown by Sellstrøm (2005) and de Wit (2005) levels of BDE-209 were 100-1000 fold higher at sites fertilized with sewage sludge compared to reference sites. When soil is amended with sludge, BDE-209 is transferred to biota, and can ultimately accumulate in organisms at the top of the food chain (UNEP/POPS/POPRC.10/10/Add.2). Applying sewage sludge to agricultural land is a way of managing sewage sludge while at the same time exploiting essential plant nutrients and organic matter in agriculture. However, as discussed above the practice contributes to the environmental releases of BDE-209. It may also contribute to human and ecological risks due to the occurrence of organic contaminants, such as BDE-209 in sludge. Accordingly, any measures to reduce the levels of BDE-209 in sewage sludge and/or measures to better control the use of sewage sludge as a fertilizer, is likely to have a positive effect by reducing BDE-209 levels in agricultural products over time.

2.4.3 Biota (biodiversity)

111. A phase-out of c-decaBDE is essential to avoid an increase of levels in wildlife already at risk. Reported adverse effects raise concerns that c-decaBDE may cause effects at population- and ecosystem level, and ultimately have implications for biodiversity (see section 2.4.1 above UNEP/POPS/POPRC.10/10/Add.2). In addition to posing a threat to Arctic ecosystems and biodiversity, both alone or in combination with other POPs (UNEP/POPS/POPRC.10/10/Add.2, UNEP/POPS/POPRC.7/INF/16), it is of concern that c-decaBDE and other substances alone or in combination can delay development and metamorphosis in frogs at environmentally relevant concentrations (Shricks et al., 2006; Qin and Xia 2010) and alter the anatomy and function of the male frog vocal system (Ganser 2009). The IUCN Red List of Threatened Species™ has identified amphibians, and among them frogs, as being the most threatened vertebrate group assessed, with around 41% at risk of extinction and urges that immediate action must be taken to protect the remaining populations of amphibians across the world (IUCN 2014, see also Stuart et al. 2004). Extinctions and large-scale declines of amphibian species have been attributed to habitat loss, pollution, fires, climate change, disease and over-exploitation (IUCN, 2014; Hayes et al., 2010). Anthropogenic chemicals may contribute to the decline in amphibian populations by influencing the immune system/ immune response, larval development and growth, ability to avoid predation, reproductive success and survival rates (Carey and Bryant 1995, see also Hayes et al., 2010). The alterations in the male frog vocal system and the delayed metamorphosis/development induced by c-decaBDE exposure may have implications for lifetime fitness (mating success, predation etc.) and ultimately population recruitment (van Allen et al., 2010; Hayes et al., 2010). Thus, the adverse effects observed in frogs suggests that c-decaBDE can be one of the pollutants contributing to declines in global frog populations.

2.4.4 Economic aspects and social costs

112. Based on information such as price, accessibility and availability of different alternatives as well as information on regulatory measures and use in different countries, the socioeconomic costs of

implementing a ban and/ or restriction on the use of c-decaBDE are considered small and outweighed by the benefits of an elimination/ regulation. An important factor as discussed in the EU restriction proposal is that although c-decaBDE is currently less expensive than the alternatives assessed, the difference in cost might gradually change in response to the increasing demand for alternatives (ECHA, 2014a).

113. The costs incurred by those manufacturers that still produce c-decaBDE depend on how a restriction/ban affects the production and market of chemical alternatives to c-decaBDE. It also depends on the technical costs associated with a transition from c-decaBDE to other alternatives at the manufacturing plants (ECHA, 2014a). However, c-decaBDE is known to be manufactured in only a few countries worldwide and a restriction/ban on the manufacture will therefore yield no direct cost (or impact) for the majority of countries worldwide, and will only affect the small number of manufacturers which still produce c-decaBDE, some of which already produce and sell alternatives. Moreover, available information suggests alternatives can be manufactured in the same manufacturing plants/production lines as c-decaBDE. Thus, transition costs for the manufacturing industry globally are assumed to be low.

114. The restriction could also affect the economy of c-decaBDE importers/vendors as well as down-stream industrial/professional users. However, most importers/vendors also import and sell other substances, including alternatives to c-decaBDE (ECHA, 2014a). Similarly, importers of c-decaBDE-containing articles may also continue to import articles with alternative FRs. Concerning down-stream industrial/professional users it is known that their capability to switch to alternatives may differ. Though most down-stream industrial/ professional users are able to transition to c-decaBDE alternatives without major additional costs, comments received from the aviation industry during a public consultation in the EU suggests that it may be difficult to immediately replace c-decaBDE in products used in aircrafts and defence hardware (ECHA, 2014a). According to the aerospace industry, this is mainly due to technical challenges, costs and time related to the development, qualification, and certification of alternative materials for aircrafts due to stringent safety and technical performance requirements, and the complexity in the supply chain (ECHA, 2014a). Similar concerns have been raised by some automotive associations, which have requested exemptions for some legacy spare parts but not for parts in ongoing production. The reasoning of automotive industry is different, as it is only dealing with practical feasibility of a substitution especially in legacy spare parts with functional properties.

115. Listing of c-decaBDE in the Stockholm Convention without a recycling exemption would mean that fractions containing c-decaBDE above a low POP content value are not to be recycled. This might have an impact on material recycling from products containing c-decaBDE. In particular, recycling of waste electrical- and electronic plastic (WEEP) and plastic from end-of-life vehicles could be affected (e.g. IVM/IVAM, 2013; see also Section 2.2.). Current volume of plastic being recycled is limited and the plastic fraction containing c-decaBDE is small (Sinha-Khetriwal et al., 2005; Widmer et al., 2005; Hicks et al., 2005; Streicher-Porte et al., 2005; see also section 2.2 paragraphs 47 and 48). The processes for recycling of ELV and WEEE is currently focused on metal recovery, and the plastic fraction are found to be less valuable because of the quality (Sinha-Khetriwal et al., 2005), Widmer et al., 2005; Hicks et al., 2005; Streicher-Porte et al., 2005). Therefore the socio-economic impact of taking the required measures so that such plastic products upon becoming waste are not recycled is considered to be low.

116. The recycling of plastic is in general desirable because of resource efficiency, but should be balanced with the importance to avoid recycling plastic containing hazardous chemicals. If in the future such material recycling is increasing, separation techniques would then have to be applied to ensure the quality of the recycled plastic material. This can lead to costs to society either in form of investment in equipment for sorting plastics waste and/or increase the need for manual labour. In the absence of achieving effective means of identifying decaBDE in waste, the impact for recycling might be significantly higher than assumed as any material containing bromine may in practice be excluded, limiting further the amount of material available for recycling. Post shredder technology to sort out the valuable plastic fraction is costly, as well as technology to extract bromine. If large throughputs are required, it can represent a barrier to market entry for new players in the WEEE recycling market.

117. On a country or regional basis an analysis of the economic impacts to recycling facilities needs to be undertaken. What could be defined as an optimal solution depends very much on the economic and cultural context in which the system operates (Sinha-Khetriwal et al., 2005). The cost of labour, the structure of the economy including the important informal sector, the existing regulatory framework and the possibilities and limits of law enforcement have to be taken into account in order to find solutions that can improve the situation with regard to environmental impacts, occupational hazards and economic revenue (Sinha-Khetriwal et al., 2005). Environmental benefits and socio

economic gain due to increased quality and use of the recycled plastic (less use of virgin plastic), as well as a higher market price may then outweigh the higher cost for recycling.

118. The market price of recycled plastic material is determined by its quality, its substitutability to replace virgin plastic and the price of virgin plastics. The presence of hazardous chemicals negatively affects the market price of recycled material (NCM, 2015b). A conclusion of a study by the Swedish Chemicals Agency (KemI) is that one of the main barriers to increase the use of recycled materials in new products is the risk that the material may contain hazardous substances (KemI, 2012). This finding is also supported by other sources (including Wäger et al., 2010; Stenvall et al., 2013; NCM, 2015b) which all highlight hazardous substances as being an obstacle to the recycling of material from WEEE products.

119. Recycling materials that contain decaBDE into various new articles may make it difficult to identify which articles contain decaBDE and treat later on. Furthermore, it is important to have control of the waste streams to avoid that decaBDE ends up in new articles leading to adverse effects in humans and economic costs due to an increase in health problems (NCM, 2014b; Bellanger et al., 2015; Hauser et al., 2015; Trasande et al., 2015; Legler et al., 2015; HEAL, 2014; see also paragraph 122). Techniques and approaches to effectively separate waste containing PBDEs, and treat them separately, are available (ECHA Background Document, 2015; Sinha-Khetriwal et al., 2005; Widmer et al., 2005; Hicks et al., 2005; Streicher-Porte et al., 2005; see also the guidance[3]). Thus a concentration limit for mixtures and articles placed on the market is necessary to ensure that a) majority of plastic articles can be recycled and b) decaBDE is not present in high concentrations in articles made from recyclate (RAC/SEAC, 2015). When installing more advanced technologies the necessary capital expenditure is considerable but thereafter the running costs are low (NCM 2014a, 2015c). Although separation techniques can mean higher operational and running cost this is likely offset by the improved and enhanced material recycling (NCM 2014a, 2015c). Lower-technology approaches, such as separation, sorting or simpler shredding of WEEE may result in relatively higher costs depending on the cost for labour work, but can also be a benefit to the society due to a higher employment. WEEE treatment processes with significant low-tech elements, can currently achieve significantly better quality to the recovered plastic than highly mechanised and automated alternatives and also higher quantified benefits (NCM, 2015a; NZMOE, 2013). The overall cost is offset by the enhanced material recycling. In addition this delivers considerable environmental benefits (NCM, 2015c).

120. According to document UNEP/POPS/COP.7/INF/22, “Waste management influences all parts of society and the economy. It concerns local, regional and national authorities and requires a legal framework, a financial mechanism, and an effective coordination between citizens and authorities at all levels. Furthermore, good waste management is not feasible without an adequate level of investment. To ensure a coherent waste management system, it is important all actions at different levels follow a commonly agreed strategy. It is therefore necessary, or at least useful, (for national and regional authorities) to discuss and decide upon a national waste management strategy. The successful implementation of any waste management system, particularly in developing countries, may require the transfer of appropriate technologies and capacity-building in accordance with Article 12 of the Convention.”

121. Besides the costs to industry, restricting the placing on the market of c-decaBDE may affect the employment in companies manufacturing the substance, as well as in actors in the supply chain including importers/exporters of c-decaBDE itself and c-decaBDE containing articles. Similarly, the employment in waste collection, sorting, recycling businesses may also be affected. The impact on employment depends e.g. on whether companies also produce and/or sell the alternatives substituting c-decaBDE. According to ECHA (2014) there are no reasons to assume differences in the labour inputs required in the production of c-decaBDE or alternative-based articles and products, and the negative impact to employment in one company (if any) should mainly be offset by positive impacts in other companies. In other words, the impacts on employment are mainly distributional and not a cost to the society as such. However, the redeployment of staff always includes some adjustment costs, e.g. related to temporary unemployment of workers when finding new jobs, although it is difficult to place a figure on these adjustment costs in practice (ECHA, 2014). Similar mechanisms will likely also affect employment in the waste- and recycling industry (see e.g. ILO, 2012; NCM, 2015b). Reduced profits will generally pull towards less employment, while potential new tasks, like

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[3] Guidance for the inventory of polybrominated dipenylethers (PBDEs) listed under the Stockholm Convention on POPs.

sorting, may increase the employment needs. The net effect on employment in the recycling sector is therefore uncertain.

122. With further regard to social costs, a new report prepared by the Nordic Council of Ministers and recent scientific publications suggests that EDCs like c-decaBDE are a great economic burden to society (NCM 2014b; Bellanger et al.,2015; Hauser et al., 2015; Trasande et al., 2015; Legler et al., 2015). According to the report by the Nordic Council of Ministers, negative effects on male reproductive health caused by EDCs costs the EU countries at least somewhere between 59 and 1200 million euros per year in lost work capacity and higher health care costs. Similar findings are reported by Hauser et al. (2015), who stipulates the costs of male reproductive disorders and diseases in the EU to nearly 15 billion euros per year (15000 millions). Bellanger et al. (2015), which perhaps is the most relevant of these studies, suggests that PBDEs along with other EDCs contribute substantially to neurobehavioural deficits and disease in the EU, with a high probability of >150 billion euro costs/year. However, the publications by the Nordic Council of Ministers, Bellanger et al. (2015) and Hauser et al. (2015) centres on specific ECDs, disorders and diseases and the total costs to society attributable to EDCs are likely much higher than indicated by these studies alone. According to Trasande et al. (2015) median costs of only those EDCs which with the highest probability can be linked to disorders and diseases, is 157 billion euros annually i.e. 1.23 % of EU gross domestic product. This finding is supported by a previous report prepared by the Health and Environment Alliance (HEAL) in the EU (HEAL, 2014). The report which includes costs related to treatment of human infertility, cryptorchidism, hypospadias, breast cancer, prostate cancer, ADHD, autism, overweight, obesity and diabetes, but not testicular cancer, stipulates that the total costs in the EU related to exposure to EDCs may be as high as 13–31 billion euros/year (HEAL, 2014).

123. Adding to the costs to the health- and welfare systems are costs relating to management of c-decaBDE containing waste and remediation of contaminated soil and sediment, which based on experience with other POPs such as PCB has shown both time consuming and costly.

124. According to the EU restriction proposal a restriction on production and use of c-decaBDE as suggested in the EUis considered a proportional measure to control the risks arising from its production and use. More specifically, thecost-effectiveness is indicated to be in the same order of magnitude (or lower) as previous restrictions under REACH on mercury, a chemical that in previous EU assessments of mercury and phenyl mercury were considered to be of equivalent level of concern to persistent, bioaccumulative and toxic substances (PBTs) and to have long range transport properties (ECHA, 2014a).

2.4.5 Movement towards sustainable development

125. Elimination of c-decaBDE is consistent with sustainable development plans that seek to reduce emissions of toxic chemicals and that links chemical safety, sustainable development and poverty reduction. Environmentally sound management of "toxic chemicals" including waste is part of Agenda 21 and the Rio declaration on environment and development (UNCED, 1992a,b). It is also part of the Strategic Approach to International Chemical management (SAICM). The Global Plan of Action of SAICM contains specific measures to support risk reduction by promoting the use of safe and effective alternatives to chemicals, including non-chemical alternatives to organic chemicals that are highly toxic, persistent and bioaccumulative (UNEP, 2006).The Overarching Policy Strategy of SAICM includes POPs as a class of chemicals to be prioritized for halting production and use and substitution with safer substitutes.

126. For circular economy, design for recycling and labelling is important to improve the quality and quantity of recycled materials (NCM, 2014c). Applying techniques and systems that allow components containing hazardous chemicals to be sorted out and disposed of in an environmentally sound manner, will make waste management more sustainable, in particular with regards to material recovery, recycling and reuse (see Section 2.2).

127. In developing countries formalization of the e-waste recycling sector i.e. the integration of the informal sector into formal waste management, can present a way forward to create sustainable employment while at the same time reducing the negative environmental- and health impacts of recycling activities resulting from the release of POPs and other hazardous chemicals (ILO, 2012).

2.5 Other considerations

128. Listing c-decaBDE in Annex A without exemptions would involve control measures that are straight forward to communicate and therefore should be effective and suitable, even in countries that have limited chemical regulatory infrastructure. Information on alternatives is readily available, and can be easily communicated as needed. With regard to environmental monitoring and biomonitoring, c-decaBDE can be added to existing programmes for monitoring other POPs. Countries that lack the

needed infrastructure to adequately monitor production and uses of c-decaBDE may require additional resources and infrastructure. However, recent developments in analytical chemistry allows BDE-209, the main congener of c-decaBDE, to be monitored and measured in parallel to other PBDEs, such as the tetra-, penta-, hexa- and heptaBDE congeners listed in the Convention, without substantial additional costs. Such advanced mass-spectrometric methods give precise information about the quantities of BDE-209 in a matrix and is therefore typically used to determine levels in environmental and biota samples. Mass-spectrometric methods can also used to determine BDE-209 levels in products/ articles in use and in waste, but is not the standard method used by waste treatment and recycling companies which typically rely on cruder sorting methods based on total bromine content for screening and sorting (UNEP/POPS/POPRC.6/2/Rev.1). Advanced analytical technologies are not available to the waste management sector on an industrial scale.

129. Parties to the Convention, for which any amendments have entered into force, have to meet the obligations under the Convention. To assist Parties in meeting their obligations, the Stockholm Convention has in the past developed inventory guidance’s for listed POPs, the objective of which has been to provide step-by-step guidance to enable Parties to establish inventories of newly listed POPs and develop strategies/action plans (Decision SC-6/12, UNEP 2014a,b). The purpose of the inventory is to assist Parties in collecting national baseline data on the listed POPs, information that can be of use to national focal points for the Convention, the coordinator of the NIP review and update process, and task teams responsible for establishing the inventory. It will also be of interest to other stakeholders concerned with the elimination of listed Pops. In addition, also other types of guidance have been developed for example guidelines developed under Basel Convention.

130. Identifying which and whether articles/products contain a certain chemical can be a challenge. Recognizing these challenges, SAICM identified the global need for information on Chemicals in Products (CiP) throughout the whole lifecycle of the product, at the International Conference on the Chemical Management (SAICM/ICCM.2/15). A voluntary program to share information about chemicals in products in the global value chain was initiated.

131. To develop effective strategies that can lead to the elimination of c-decaBDE, Parties need to acquire a sound understanding of their national situation concerning these chemicals. If c-decaBDE is listed in the Convention, the Conference of the Parties may therefore update the “Guidance for the inventory of polybrominated diphenyl ethers (PBDEs) listed under the Stockholm Convention on Persistent Organic Pollutants”to assist Parties to the Convention in meeting their obligations under the Convention and assisting them in their phase-out of c-decaBDE (UNEP 2014a).

3. Synthesis of information

3.1 Summary of risk profile information

132. At its 10th meeting in 2014 the POPs Review Committee adopted the risk profile and decided that the decabromodiphenyl ether component (BDE-209) of c-decaBDE 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.

133. BDE-209 is highly persistent in soil and sediments, but it is also known to debrominate to lower brominated PBDEs in the environment and biota.Due to debromination, organisms are moreover co-exposed to a complex mixture of PBDEs, including the already listed POPs BDEs.

134. BDE-209 is an ubiquitous global contaminant that is detected in urban, rural and remote regions across the globe. In the Arctic and other remote regions BDE-209 is found in various environmental compartments including air, sediment, snow, ice and biota. Both oceanic and atmospheric processes contribute to the long-range environmental transport of BDE-209, but binding to atmospheric particles is believed to be the main mechanism.

135. Due to the extremely low water solubility of BDE-209 the most important exposure route in aquatic and terrestrial food webs is through the diet. Although some studies do not demonstrate BDE-209 bioaccumulation and trophic dilution has been observed (TMF<1), bioaccumulation has been reported for a number of aquatic and terrestrial organisms.The equivocality in the available bioaccumulation data of BDE-209 largely reflects species differences in uptake, metabolism and elimination.

136. C-decaBDE is widely detected in biota and high body burdens have been demonstrated in some species.BDE-209 can transfer from mother to off-spring and exposure takes place during early development. Maternal transfer to eggs and offspring has been reported in fish, amphibians, birds and reindeer.In humans, exposure to BDE-209 takes place in the early phases of development in utero via

placental transfer and postnatally via mother's milk. In addition, infants and toddlers are reported to have higher body burdens of BDE-209 and other PBDEs than adults due to a higher exposure to dust.

137. There is evidence that BDE-209 can result in adverse effects to reproductive health and output in fish, earthworm, mouse and rats as well as developmental- and neurotoxic effects in amphibians, rodents and humans. Furthermore, there is a concern that BDE-209 and other PBDEs combined may cause developmental neurotoxicity in both humans and wildlife at environmentally relevant concentrations.Available toxicity data shows that BDE-209may act as an endocrine disruptor, and interfere with thyroid hormonehomeostasis in fish, amphibians, rat, mice and humans, and possibly with steroid hormone homeostasis. In combination, debromination and co-exposure to BDE-209 and other similarly acting PBDEs, as well as the high persistency of BDE-209 in sediments and soils, increase the likelihood for chronic long-term adverse effects.

3.2 Summary of risk management evaluation information

138. A positive impact on globally sustainable development is expected from elimination of c-decaBDE. However, if production, use and waste management of c-decaBDE are not controlled, the levels in the environment including humans and wild life will likely continue to increase, even in remote locations.

139. C-decaBDE is a synthetic substance with no known natural occurrence. Today c-decaBDE is manufactured only in a few countries globally. Many countries have already restricted or initiated voluntary programs to end the use of c-decaBDE. This has successfully led to use of alternative FRs, redesign or alternative methods to fulfil the FR requirements of the product. However, the environmental releases of c-decaBDE and its main constituent BDE-209 are continuing in all regions investigated.

140. Although releases may also occur during production, c-decaBDE emissions are mainly attributed to releases from articles in use and waste. A global ban on production and use of c-decaBDE combined with proper waste management measures is therefore essential to achieve a future reduction in exposure of humans and the wildlife.

141. C-decaBDE has many applications and is used in many different sectors of society. It is used in EEE like computers and TVs, in wires and cables as well as in adhesives, sealants, coatings, inks and pipes. C-decaBDE is also extensively used in commercial textiles for public buildings, in textiles for domestic furniture and in the transportation sector. Globally up to about 90% of c-decaBDE ends up in plastics, primarily in electronics, while the remaining ends up in coated textiles, upholstered furniture and mattresses.

142. The automotive and aviation industry are in the process of phasing out c-decaBDE. However, some industry observers have raised a concern for service and some legacy spare parts for use in articles already in use, as well as for aircrafts currently in production under existing type certificates. The justification provided relates to technical and economic issues, and suggests a possible need for exemptions in the transportation sector. However, fire-safety requirements and certification schemes do not necessarily require the use of c-decaBDE or other FRs. In the case that replacement with another FR is necessary, chemical alternatives are available that can substitute c-decaBDE in most plastic and textile applications which are still in mass production. However due to the requirements for changes in some legacy spare parts which would need testing often in original vehicles, which are no longer in mass production and often have not been for many years, the possibility of testing does not exist. It is furthermore likely that manufacturers of such legacy spare parts will stop their manufacture. This can ultimately result in unavailable or untested and thus dangerous replacement parts, or non-compliance with national obligations to deliver such parts for at least 10 years after mass production. Yet, in many cases, flame retardancy can also be achieved through the use of alternative techniques such as inherent flame-resistant material and use of different technical solutions i.e. barriers or complete redesign of the product. These alternative techniques can be used in a multitude of materials and applications, and are used in textiles, electronics, aircraft, and in other means of transportation.

143. The service-life of products containing c-decaBDE varies globally but an average of 10 years can be estimated, hence end-of-life products will enter the waste stream for many years and be a source to future emissions. According to the Convention (Article 6(1)(d)(ii)), waste containing c-decaBDE 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, thereby efficiently removing the emissions and related exposures to c-decaBDE in waste. Different techniques for handling POPs containing waste in an environmentally sound manner are available. Controlled incineration, in state of the art facilities with continuous monitoring, and strict compliance with Convention BAT/BEP guidelines, is one way to dispose of

waste containing c-decaBDE and may allow energy recovery. Incineration at high temperatures is generally considered to effectively destroy POPs like c-decaBDE, with formation of small amounts dioxins and furans. Where destruction or irreversible transformation does not represent the environmentally preferred option, or the POPs content is low, countries may allow such wastes to be disposed by other environmentally sound methods e.g. in specially engineered landfills.

144. Sorting and separating waste fractions can be used to achieve more sustainable waste management, and separation techniques includes manual and automated sorting of waste components also those containing hazardous chemicals, such as brominated FRs. Advanced separation techniques are already in use in the waste management sector but are not widely available yet. However, in developing countries, waste handling mostly occurs in the informal sector where modern industrial processes are not used, and sorting is conducted manually without the use of adequate protection and ventilation resulting in human and environmental exposures. In developing countries, integration of the informal sector into formal waste management, can present a way towards increased sustainability.

145. A small number of Parties have suggested a possible need for a recycling exemption. Others opposed on exemption for recycling because they were concerned about articles, products in use, and recycled products containing decaBDE being exported especially to developing countries and countries with economies in transition due to lack of capacity to identify and analyse products containing deca BDE. Yet, recycling of materials containing c-decaBDE will inevitably result in wider human and environmental contamination and dispersal of PBDEs. It should be avoided if the aim is to eliminate emissions and exposure to c-decaBDE. It was recently reported that plastic pellets from recycled material contaminated with c-decaBDE is subject to export and that this recyclate may end up in products where they can pose a hazard to human health. Recent studies have detected c-decaBDE in food-contact materials and in children’s toys made from plastic pellets originating from recycled plastic. Moreover, the socio-economic impacts of not allowing recycling of c-decaBDE above a POP limit value to be determined could be limited, an important reason being that recycling rates of c-decaBDE containing plastics and textiles are low. However the automotive industry sector has indicated that they need to meet a stringent recycling quota of 85% in Europe and without a recycling exemption, these legal obligations cannot be fulfilled. However, based on the information received and assessed in this RME, the socio-economic impact of taking the required measures so that such plastic products upon becoming waste are not recycled is considered to be low.

146. Labelling of newly produced articles containing decaBDE could be useful when articles become waste.

3.3 Suggested risk management measures

147. The most efficient control measure to reduce the releases of c-decaBDE would be to list the decabromodiphenyl ether component (BDE-209) of c-decaBDE in Annex A without exemptions. Listing the decabromodiphenyl ether component (BDE-209) of c-decaBDE in Annex A would also mean that the provisions of Article 3 on export and import and of Article 6 on identification and sound disposal of stockpiles and waste would apply.

148. Based on the information submitted during the risk management evaluation and the collective experience reported, there may be challenges for some sectors, i.e., legacy spare parts for the aerospace and automotive industries. Some parties identified challenges for recycling. Because of the concerns about articles, products in use, and recycled products containing decaBDE being exported especially to developing countries and countries with economies in transition, other experts opposed recycling exemption due to lack of capacity to identify and analyse products containing deca BDE. Additional risk management measures could include an obligation to label new articles that contains decaBDE.

4. Concluding statement

149. Having decided that the decabromodiphenyl ether component (BDE-209) of c-decaBDE, 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;

150. Having prepared a risk management evaluation and considered the management options and noting that non-persistent organic pollutant alternatives to decabromodiphenyl ether are available;

151. 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 the decabromodiphenyl ether component (BDE-209) of c-decaBDE in Annex A with a specific exemption for some critical

legacy spare parts that still need to be defined in the automotive and aerospace industries. Since the information on small and medium enterprices in the textile industry in developing countries is very limited, it is not possible to conclude that exemptions are unnecessary for them.

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