

Stockholm Convention on Persistent Organic Pollutants

**Persistent Organic Pollutants Review Committee  
(POPRC)**

**DRAFT RISK MANAGEMENT EVALUATION**

**for**

**Commercial octabromodiphenyl ether**

Draft prepared by:

The ad hoc working group on commercial octabromodiphenyl ether

**April, 2008**

**Draft Risk Management Evaluation for Commercial  
octabromodiphenyl ether**

**Note:**

In accordance with the procedure laid down in Article 8 of the Stockholm Convention, this draft was prepared by the Persistent Organic Review Committee (POPRC) during its intersessional work.

Parties and observers to the Stockholm Convention are invited to provide technical and substantive comments on this draft. Comments received will be considered by the ad hoc working group and the revised draft will be made available for the fourth meeting of the POPRC (13-17 October 2008 in Geneva). Please submit your comments to the Secretariat of the Stockholm Convention preferably by e-mail no later than **18 May, 2008** to:

Secretariat of the Stockholm Convention  
POPs Review Committee  
11-13 chemin des Anémones  
CH-1219, Châtelaine, Geneva, Switzerland  
Fax: (+41 22) 917 80 98  
**E-mail: [ssc@pops.int](mailto:ssc@pops.int)**

---

Ad hoc working group on commercial octabromodiphenyl ether

Chair: Ms. Jacqueline Alvarez (Uruguay)

Drafter: Mr. Sylvain Bintein (France)

Members: Ms. Anahit Aleksandryan (Armenia), Prof. Ian Rae (Australia), Dr. Robert Chénier (Canada), Mr. Jianxin Hu (China), Dr. Alfredo Cueva (Ecuador) Chair from May, Mr. Sylvain Bintein (France)\*\*, Prof. Masaru Kitano (Japan), Dr. Mohammed Khashashneh (Jordan), Ms. Evelin Fabjan (Slovenia)\*, Dr. José V. Tarazona (Spain), Prof. Bo Wahlström, Ms. Maria Delvin (Sweden), Ms. Bettina Hitzfeld (Switzerland)\*\*, Ms. Leena Ylä-Mononen (United Kingdom), Ms. Jacqueline Alvarez (Uruguay)\* Chair until May, Dr. Ali El-Shekeil (Yemen)

Observers: Mr. Gary Fan (Australia), Mr. Lee Eeles (Australia), Ms. Zhifang Wang (China), Mr. Timo Seppälä (Finland), Mr. Takashi Fukushima (Japan), Ms. Misako Kurakata (Japan), Dr. Maria Dolores Hernando Guil (Spain), Dr. Tala Henry (United States of America), Mr. Chris Blunck (United States of America), Dr. Susan Gardner (United States of America), Mr. Kenneth Moss (United States of America), Mr. Mark Trewhitt (CropLife International), Dr. Joseph DiGangi (Environmental Health Fund), Dr. Mariann Lloyd-Smith (International POPs Elimination Network), Mr. Cyrille Siewe (UNEP)\*Member whose term ends in May 2008

\*\*Member whose term starts in May 2008

## TABLE OF CONTENTS

<b>1. Introduction .....</b>	<b>2</b>
1.1 Chemical identity of the proposed substance .....	2
Background .....	2
Chemical identity of the proposed substance .....	2
1.2 Conclusions of the Review Committee of Annex E information .....	4
1.3 Any national or regional control actions taken .....	4
European Union .....	5
Switzerland .....	6
Norway .....	6
United States of America .....	6
Canada .....	8
Asia .....	9
The UNECE Convention on Long-range Transboundary Air Pollution .....	9
OSPAR Commission .....	9
Helsinki Commission (HELCOM) .....	9
OECD (Organisation for Economic Cooperation and Development) .....	9
<b>2. Production, use and releases .....</b>	<b>10</b>
2.1 Levels and trends of production .....	10
Overall demand and production .....	10
2.2 Use of c-OctaBDE .....	11
Use volumes .....	11
Use types .....	12
2.3 Global demand in the future .....	13
2.4 Emissions from production and processing .....	13
2.5 Emissions from handling and transport .....	16
2.6 Emissions from the use of products containing c-OctaBDE .....	16
Volatilisation .....	16
Leaching .....	17
“Waste remaining in the environment” .....	17
2.7 Emissions from waste containing c-OctaBDE .....	19
Emissions at disposal .....	19
Emissions after disposal .....	19
Emissions from recycling and dismantling .....	21
<b>3. Summary information relevant to the risk management evaluation .....</b>	<b>21</b>
3.1 Management options .....	25
Efficacy and efficiency of possible control measures .....	26
Waste handling .....	26
3.2 Substitution .....	27
3.3 Measures to reduce emissions .....	41
3.4 Impacts on society of implementing possible control measures .....	42
Benefits of phasing-out c-OctaBDE .....	43
Cost implications for industry .....	43
Cost implications for consumers .....	45
Cost implications for state budgets .....	45
3.6 Identification and discussion of possible management options under the Stockholm Convention .....	47
Possible management options .....	47
Discussion of options .....	48
<b>4. Synthesis of information .....</b>	<b>49</b>
4.1 Summary of evaluation .....	49
4.2 Elements of a risk management strategy .....	50
Concluding statement .....	51

Deleted: 3

Deleted: 4

Deleted: 5

Deleted: 5

Deleted: 5

Deleted: 6

Deleted: 7

Deleted: 7

Deleted: 7

Deleted: 8

Deleted: 8

Deleted: 8

Deleted: 8

Deleted: 8

Deleted: 9

Deleted: 9

Deleted: 11

Deleted: 11

Deleted: 11

Deleted: 11

Deleted: 14

Deleted: 14

Deleted: 14

Deleted: 15

Deleted: 15

Deleted: 16

Deleted: 16

Deleted: 17

Deleted: 17

Deleted: 17

Deleted: 18

Deleted: 19

Deleted: 19

Deleted: 24

Deleted: 25

Deleted: 25

Deleted: 26

Deleted: 27

Deleted: 27

Deleted: 28

Deleted: 28

Deleted: 29

Deleted: 29

Deleted: 29

Deleted: 30

Deleted: 30



## Executive Summary

The term “c-OctaBDE” designates a commercial mixture containing polybrominated diphenyl ethers, typically consisting of penta- to deca-bromodiphenyl ether congeners. c-OctaBDE has been used as an additive flame retardant mainly in **the** plastics industry for polymers used for housings of office equipment. The estimated annual world-wide production of commercial OctaBDE (c-OctaBDE) in 1994 was 6,000 tonnes. Globally 70% of c-OctaBDE has been used in acrylonitrile butadiene styrene (ABS). Other minor uses included high impact polystyrene (HIPS), polybutylene terephthalate (PBT) and polyamide polymers.

Deleted: -

Production was recently phased out in the EU, Norway, Switzerland, Canada and the USA. There is no information available that indicates it is still being produced in developing countries. It has been reported that it is at present essentially impossible to buy c-OctaBDE at global level. Therefore, releases from production, handling and processing in these countries/regions **should** have already ceased or are **probably** close to zero. Releases from use, disposal and recycling of products are due to volatile and particulate losses. The volatile loss over a ten year lifetime of a product is **estimated at** 0.54% of its c-OctaBDE content. The corresponding estimate for particulate loss is 2%. These releases enter industrial/urban soil **and dust** (~75%), air (~0.1%) and surface water (~24.9%). Releases during the service life of products and particularly at their disposal contribute the most significant share to the total releases. Releases after disposal **may be** considered **to be low**. **However possible long-term increases in levels as a result of releases from waste sites might need to be considered further.**

**Comment [J1]:** Not true: Available for purchase in China:  
[http://www.sinobrom.cn/cgi/search-en.cgi?f=product\\_en+company\\_en\\_1\\_%20&t=product\\_en&w=product\\_en&cate2=Flame%20Retardant&n=3](http://www.sinobrom.cn/cgi/search-en.cgi?f=product_en+company_en_1_%20&t=product_en&w=product_en&cate2=Flame%20Retardant&n=3)

Deleted: are

Deleted: negligible

In the light of the ban and phase out of c-OctaBDE, the availability of practicable and economically viable substitutes for all uses has already been demonstrated in practice. The human health or environmental impacts of these alternatives made them preferable alternatives over c-OctaBDE.

High levels of the components of c-OctaBDE are detected in the environment. They have severe toxic properties and have been shown to be persistent and bioaccumulative. They thus represent a potential risk for future generations. Those findings have resulted in voluntary and regulatory phase-outs of c-OctaBDE in several regions in the world. Since this is a global, transboundary problem, global actions to phase out c-OctaBDE should be considered.

**The components of c-OctaBDE are also unintentionally formed through debromination of higher substituted congeners, including commercial decabromodiphenyl ether (c-DecaBDE). Control measures that address c-DecaBDE would be an appropriate measure to prevent further formation of c-OctaBDE and other BDE congeners in the environment. This could be accomplished by also listing c-OctaBDE in Annex C.**

Several countries have reported that they would have problems regulating a commercial mixture of OctaBDE. Listing **hexa-, hepta-, octa-, and nonabromodiphenyl ether congeners in Annex A as the components of c-OctaBDE and using the following relevant congeners for enforcement purposes** would be consistent with existing national legislations and would facilitate the national monitoring and control of emissions, production and use: **BDE153 (hexaBDE); BDE175/183 (heptaBDE); BDE196, BDE197, BDE203 (octaBDE); and BDE206, BDE207 (nonaBDE).**

Deleted: the polybrominated diphenylethers (PBDE)

Deleted: having POP characteristics<sup>1</sup>

Deleted: .

## Conclusion and recommendation

Having evaluated the risk profile for c-OctaBDE, and having concluded that this chemical is likely, due to the characteristics of its components, as a result of long-range environmental

transport, to lead to significant adverse effects on human health and the environment, this risk management evaluation has been prepared, as specified in Annex F of the Convention.

In accordance with paragraph 9 of Article 8 of the Convention the Committee recommends to the Conference of the Parties to consider listing and specifying the related control measures of **hexa-, hepta-, octa-, and nonabromodiphenyl ethers** in Annex A and Annex C of the Convention, as described above and using **BDE153 (hexaBDE); BDE175/183 (heptaBDE); BDE196, BDE197, BDE203 (octaBDE); and BDE206, BDE207 (nonaBDE) as markers for enforcement purposes.**

Deleted: the PBDE congeners having POP characteristics

## Introduction

### 1.1 Chemical identity of the proposed substance

#### Background

The European Union and its Member States, which are Parties to the Stockholm Convention, submitted a proposal in July 2006 for listing **commercial** octabromodiphenyl ether (**c-OctaBDE**) in Annex A of the Stockholm Convention. At its third meeting in November 2007, the Persistent Organic Pollutants Review Committee, decided in accordance with paragraph 7 (a) of Article 8 of the Convention and paragraph 29 of decision SC-1/7 of the Conference of the Parties, to establish an intercessional working group to prepare a risk management evaluation that includes an analysis of possible control measures for commercial octabromodiphenyl ether in accordance with Annex F to the Convention (UNEP, 2007a).

The term “c-OctaBDE” designates a commercial mixture containing polybrominated diphenyl ethers with varying degrees of bromination, typically consisting of penta- to deca-bromodiphenyl ether isomers.

These synthetic brominated compounds have mainly been used as flame retardants principally in the plastics industry for flame retarded polymer products, typically the housings of office equipment and business machines. According to the required flame retardancy, the finished products contain typically 5 to 30% c-OctaBDE by weight. The main use of c-OctaBDE is in ABS polymers with 12 to 18% weight loadings. Minor uses concern HIPS, PBT and polyamide polymers, at typical loadings of 12 to 15% weight in the final product.

PBDEs are flame retardants of the additive type, i.e. they are physically combined with the material being treated. This means that the flame retardant **can** diffuse out of the treated material to some extent and it is assumed that the total emission of c-OctaBDE to the environment is dominated by volatile losses from polymers over their service life.

Deleted: may

Because of the chemical and toxic properties of its main components, in particular isomers of hexabromodiphenyl ether (HexaBDE) and heptabromodiphenyl ether (HeptaBDE), and their wide spread occurrence in the environment and in humans c-OctaBDE causes concern in many regions in the world<sup>2</sup>.

#### Chemical identity of the proposed substance

This evaluation considers the following commercial flame retardant product:

---

<sup>2</sup> This could be updated if needed (see footnote 1)

- IUPAC Name: Diphenyl ether, octabromo derivative (c-octabromodiphenyl ether, c-OctaBDE)
- CAS Number: 32536-52-0
- EINECS Number: 251-087-9
- Chemical Formula of OctaBDE isomers: C<sub>12</sub>H<sub>2</sub>Br<sub>8</sub>O

There are several components in the commercial product and so any assessment of the commercial product **needs to include** the individual components. The commercially supplied OctaBDE is a complex mixture consisting (as of 2001 within the EU member States) typically of ≤ 0.5% pentabromodiphenyl ether isomers (PentaBDE), ≤ 12% HexaBDE, ≤ 45% HeptaBDE, ≤ 33% OctaBDE, ≤ 10% nonabromodiphenyl ether isomers (NonaBDE) and ≤ 0.7% decabromodiphenyl ether (DecaBDE). **The congener composition of widely-used commercial octaBDE mixtures, DE-79 and Bromkal 79-8DE was recently determined by LaGuardia et al.<sup>3</sup> DE-79 was found to contain 15 PBDE congeners with major constituents including HexaBDE (BDE153, 8.7%), HeptaBDE (BDE175/183, 42%), OctaBDE (BDE197, 22%; BDE196, 10.5%; BDE203, 4.4%), and NonaBDE (BDE207, 11.5%). The DE-79 commercial octaBDE mixture also has been found to contain polybrominated dibenzofurans (PBDF).<sup>4</sup> Bromkal 79-8DE contained 13 PBDE congeners with major constituents including HeptaBDE (BDE175/183, 13%), OctaBDE (BDE197, 10.5%; BDE196, 3.1%; BDE203, 8.1%), NonaBDE (BDE206, 7.7%, BDE207, 11.2%), and surprisingly DecaBDE in large quantities (BDE209, 50%).** The composition of older products or products from non-EU countries may be different from this (European Commission 2003a). Table 1 shows typical composition of c-OctaBDE flame retardants (UK, 2007).

Deleted: requires an assessment of

Table 1: Typical composition of c-OctaBDE flame retardants

Main components	% by weight					2006 <sup>f</sup> DE-79	2006 <sup>f</sup> Bromkal 79
	Up to 1994 <sup>a</sup>	1997 <sup>c</sup>	2000 <sup>d</sup>	2001 <sup>e</sup>	2006 <sup>f</sup>		
PentaBDE	10.5-12.0 <sup>b</sup>		1.4-12.0 <sup>b</sup>	≤0.5			
HexaBDE		5.5		≤12	10.5		
HeptaBDE	43.7-44.5	42.3	43.0-58.0	≤45	45.5		1
OctaBDE	31.3-35.3	36.1	26.0-35.0	≤33	37.9		2
NonaBDE	9.5-11.3	13.9	8.0-14.0	≤10	13.1		1

<sup>3</sup> LaGuardia MJ, Hale R, Harvey E (2006) Detailed polybrominated diphenyl ether (PBDE) congener composition of the widely used penta-, octa-, and deca-PBDE technical flame-retardant mixtures, *Environ Sci Technol* 40:6247-6254

<sup>4</sup> Hanari N, Kannan K, Miyake Y, Okazawa T, Kodavanti PR, Aldous KM, Yamashita N (2006) Occurrence of polybrominated biphenyls, polybrominated dibenzo-p-dioxins, and polybrominated dibenzofurans as impurities in commercial polybrominated diphenyl ether mixtures, *Environ Sci Technol* 40:4400-4405

DecaBDE	0-0.7	2.1	0-3.0	≤0.7	<b>1.3</b>	4
---------	-------	-----	-------	------	------------	---

- Note:
- a) The 1994 data are taken from WHO (1994).
  - b) The value is for the total amount of PentaBDE + HexaBDE.
  - c) The 1997 data are from a composite sample from three suppliers to the EU at that time (Stenzel and Nixon, 1997).
  - d) The 2000 data are taken from RPA (2001) and represent the composition reported to the OECD under a Voluntary Industry Commitment.
  - e) The 2001 data from the Great Lakes Chemical Corporation represent the mean composition based on random sampling of selected production lots from August 2000 to August 2001.
  - f) **The data are from: LaGuardia MJ, Hale R, Harvey E (2006) Detailed polybrominated diphenyl ether (PBDE) congener composition of the widely used penta-, octa-, and deca-PBDE technical flame-retardant mixtures, Environ Sci Technol 40:6247-6254**
- Note that DE-79 was manufactured by Great Lakes Chemical Corporation, USA. Bromkal 79-8DE was manufactured by Chemische Fabrik Kalk, Germany**

## 1.2 Conclusions of the Review Committee of Annex E information

Annex E of the Stockholm Convention requires a Risk Profile to be developed to evaluate whether the chemical is likely, as a result of its long-range environmental transport, to lead to significant adverse human health and/or environmental effects, such that global action is warranted.

A Risk Profile for c-OctaBDE (UNEP, 2007a) was developed and accepted in 2007 (UNEP, 2007a). **In Decision POPRC-3/6, the POP Review Committee concluded as follows (UNEP, 2007b):**

*“Taking into account the high potential of the components of commercial octabromodiphenyl ether to persist in the environment, to bioaccumulate and biomagnify and to represent a hazard for humans and wildlife at very low levels, The Persistent Organic Pollutants Review Committee:*

- *Invites the intersessional working group on commercial octabromodiphenyl ether which prepared the risk profile to explore any further information on including octabromodiphenyl ether and nonabromodiphenyl ether related to risk estimations and bioaccumulation, including the environmental and health relevance of de-bromination, and, if appropriate, to revise the risk profile for consideration by the Committee at its fourth meeting.*
- *Decides, in accordance with paragraph 7 (a) of Article 8 of the Convention, that the hexa- and hepta bromodiphenyl ether components of the commercial octabromodiphenyl ether are likely, as a result of long-range environmental transport, to lead to significant adverse human health and/or environmental effects such that global action is warranted;*
- *Decides, in accordance with paragraph 7 (a) of Article 8 of the Convention, and taking into account that a lack of full scientific certainty should not prevent a proposal to list a chemical in the annexes of the Convention from proceeding, that the octa- and nona bromodiphenyl ether components of the commercial octabromodiphenyl ether are likely, as a result of long-range environmental transport, to lead to significant adverse human health and/or environmental effects such that global action is warranted.”*

**Comment [J2]:** This is not a reference for the Risk Profile

**Deleted:** The

**Comment [J3]:** These quotes come from Decision POPRC-3/6 not the Risk Profile

## 1.3 Any national or regional control actions taken

Most developed countries have taken some actions to limit the production and use of c-OctaBDE. Until 2004, production was situated in the Netherlands, France, USA, Japan, UK and Israel (UNEP 2008, BSEF 2006) but it is no longer produced in the EU, USA, or Japan. Information about production in developing countries is sparse e.g. there is no production or uses in Armenia (UNEP 2008, Armenia). In addition, a number of international measures have also been taken related to c-OctaBDE.

**Comment [J4]:** Octa appears to be produced and sold in China by SinoBrom. See [http://www.sinobrom.cn/cgi/search-en.cgi?f=product\\_en+product\\_en\\_1\\_&id=401501&t=product\\_en\\_1\\_](http://www.sinobrom.cn/cgi/search-en.cgi?f=product_en+product_en_1_&id=401501&t=product_en_1_)

**Deleted:** and the Pacific Rim and there is no information that it is produced

## European Union

Within the European Union, there were two reported producers of c-OctaBDEs in the EU IUCLID database in 1994. However, both companies stopped production within the EU (1996/1998).

The amount imported into the EU in 1999 was estimated as 450 tonnes/year as the substance itself, with around 1,350 tonnes/year imported in finished articles (European Commission, 2003a). In the light of the legislative restrictions that are in place in the EU, import of c-OctaBDE as such or in articles is prohibited, since "import" is also considered as "placing on the market" in the EU legislation.

In the EU, OctaBDE was identified as a priority substance for risk assessment under Regulation 793/93/EEC. Based on the risk assessment, UK prepared a Risk Reduction Strategy and analysis of advantages and drawbacks of possible measures (RPA, 2002).

As a result of the European Union Risk Assessment process, Directive 2003/11/EC was adopted in 2003 (European Union, 2003). This Directive prohibits the placing on the market and use of OctaBDE as a substance or as a constituent of substances or of preparations in concentration higher than 0.1% by mass. Articles may not be placed on the market if they, or flame-retarded parts thereof, contain OctaBDE in concentrations higher than 0.1% by mass. Member States were obliged to implement the prohibition by 15 February 2004 and apply the measures from 15 August 2004.

The European Union banned the use of OctaBDE and decaBDE in new electronics and electronic products as of July 1, 2005 pursuant to the Directive on restrictions on hazardous substances (RoHS) Directive (European Union, 2002a).

To control and minimise environmental impacts from products containing PBDEs that are already in use, Directive 2002/96/EC on waste electrical and electronic equipment (WEEE) sets specific requirements with respect to collection, recovery, permitting of treatment installations, treatment standards and separation (European Union, 2002b). Following the objective to improve environmental performance of all operators and in particular of those operators involved in the treatment of WEEE, the Directive in its article 5 obliges Member States to adopt appropriate measures to minimise disposal as unsorted waste and to achieve a high level of separate collection of WEEE. Since 13 August 2005 systems for collection from households at least free of charge and take-back obligations were required. By December 31, 2006 at the latest a separate collection of at least four kilograms of WEEE per inhabitant per year from private households shall be achieved. Following article 6 treatment is only allowed in authorised installations complying with minimum technical requirements set out in Annex III of the Directive. In addition minimum treatment requirements were specified such as the separation of all brominated flame retardant containing plastics prior to being recovered or disposed of according to article 4 of Council Directive 12/2006. In addition specific targets are set in article 7 of the Directive as concerns recovery rates per appliance (by weight).

Brominated diphenylethers are mentioned as hazardous substances in the list of priority substances in the field of water policy with the aim of progressively reducing pollution from these substances (European Union, 2000).

Prior to the Community level control measures on c-OctaBDE, several EU Member States had already introduced voluntary measures or national restrictions to phase out c-OctaBDE.

### Switzerland

The Ordinance on Risk Reduction related to the use of certain particularly dangerous substances, preparations and articles (Switzerland, 2005) severely restricts marketing and use of OctaBDE in Switzerland. It is prohibited to place on the market and to use OctaBDE or substances and preparations with an OctaBDE content equal to or greater than 0.1% by mass, except for analysis and research purposes and it is prohibited for new articles to be placed on the market if they have parts that are treated with flame retardants containing c-OctaBDE exceeding 0.1% by mass. The prohibition in the ORRChem is the application of the EU Directive (European Union, 2003).

### Norway

In Norway the use of c-OctaBDE is banned since 1.7.2004. From 1.1.2004, products containing more than 0.25 % c-OctaBDE are classified as hazardous waste when they are discarded (UNEP, 2007c Norway). **In 2008, Norway prohibited a ban on new products containing decaBDE leaving the transport sector as the only exemption.**

### United States of America

In the USA c-OctaBDE is subject to EPA's TSCA Inventory Update Reporting Rule, under which production and import information is periodically collected. For the 2002 reporting year, U.S. production of c-OctaBDE was estimated in the range of 450 to 4,500 tonnes (UNEP 2007, USA).

A voluntary phase out of production of c-OctaBDE went into effect January 1, 2005, followed by a Toxic Substances Control Act (TSCA) Significant New Use Rule (US EPA, 2006) to require notification upon any restart of production or import, for any use.

According to BSEF several American States have passed legislation restricting or banning c-OctaBDE in the USA (BSEF, 2006):

California: **Legislation bans pentaBDE and octaBDE after 1 June 2006**

Hawaii: Legislation signed by Gov. Linda Lingle in 2004 **bans pentaBDE, octaBDE or any other chemical formulation that is part of these classifications on or after 1 January 2006.**

Illinois: **Legislation bans octaBDE and pentaBDE as of 1 January 2006 and requires the Illinois Environmental Protection Agency to submit to the General Assembly and the Governor a report that reviews the latest available scientific research related to the effects of decaBDE. The Agency released the report 20 March 2007 concluding that from the available science, decaBDE can and should be eliminated.**<sup>5</sup>

**Deleted:** Bill

**Deleted:** banning all PBDEs introduced in 2003, but decaBDE later removed by bill's author; phase out of OctaBDE only signed into law.

**Deleted:** phases out OctaBDE

**Deleted:** Bill

**Deleted:** to phase out all PBDEs introduced in 2005; amended to remove decaBDE. Bill as signed bans manufacture of Octa-BDE

<sup>5</sup> <http://www.epa.state.il.us/reports/decabde-study/index.html>

Maryland:	Maryland <b>legislation</b> signed in 2005 prohibits manufacture, processing, sale or distribution of new products containing OctaBDE <b>and PentaBDE and required the Department of Environment to report on the use of DecaBDE and recommend restrictions on its use and sale.</b>	Deleted: bill
Maine:	<b>Legislation</b> signed into law in 2004, <b>prohibits the sale and distribution of new products containing penta-BDE or octa-BDE as of 1 January 2006. The law states that Maine will ban deca-BDE if a “safer, nationally available alternative is identified” as of January 1, 2008 and required The Department of Environmental Protection and the Department of Human Services, Bureau of Health to annually submit a report regarding the regulation and dangers of brominated flame retardants, including the availability of safer alternatives to deca-BDE. A second law enacted June 2007 bans new uses of DecaBDE in mattresses and upholstered furniture effective 1 January 2008 and phases out existing uses of Deca in televisions and computer housings by 1 January 2010. The law also authorizes the state to adopt rules to ban other harmful alternative flame retardants for these same products, if there are safer alternatives that meet fire safety standards; requires product manufacturers to notify sellers if these products contain DecaBDE, effective 1 January 2008, and for the state to assist retailers; Authorizes participation in an interstate clearinghouse on PBDEs and BFRs; Adds state authority to require compliance certification; and Requires continued reporting to the Legislature every two years on hazard and risk assessments and alternatives to the use of all brominated flame retardants.</b>	Deleted: Bill Deleted: requires phase-out of any product containing OctaBDE, effective January 1, 2006.
Michigan:	<b>Legislation</b> requires as of <b>1 January 2006, PentaBDE and OctaBDE</b> may no longer be manufactured, processed or distributed in Michigan.	Formatted: Font color: Dark Blue Deleted: Bill Deleted: 3, Deleted: 5
Minnesota:	<b>Bans penta- and octa-BDE in products effective 1 January 2008 and required a study of deca-BDE to be reported to the legislature by 15 January 2008.<sup>6</sup> The report notes that deca-BDE has been determined to break down into more toxic PBDE congeners including Hexa-, Hepta-, Octa-, and Nona-BDES. By 1 January 2008, the state shall make available for purchase and use by all state agencies equipment, supplies, and other products that do not contain polybrominated diphenyl ethers, unless exempted.</b>	
New York:	<b>Legislation passed in 2004 requires ban on PentaBDE and OctaBDE as of January 2006. The bill also establishes a Task Force on Flame Retardant Safety to study the risks associated with deca-BDE and the availability, safety and effectiveness of alternatives to such flame retardant.</b>	Deleted: Bill
Oregon:	<b>Legislation</b> passed in 2005 ends use of OctaBDE and PentaBDE as of January 2006, and requires the state to track all brominated flame retardants and report to the legislature on a summary review of relevant new studies on brominated flame retardants and recent findings and rulings by the US EPA and the EU; Recommendations regarding restrictions on the disposal of products containing brominated flame retardants; and any other recommendations to protect public health and the environment from brominated flame retardants.	Deleted: requires as of January 2006, the manufacture of products containing more than 1/10th of 1 percent of OctaBDE will be prohibited. State is convening Task Force to better understand brominated flame retardants. Formatted: Justified, Indent: Left: 0", Hanging: 1.13", Space Before: 0 pt, After: 0 pt Deleted: Bill Deleted: .

<sup>6</sup> Minnesota Pollution Control Agency (2008) Decabromodiphenyl ether (Deca-BDE) <http://proteus.pca.state.mn.us/publications/reports/lrp-ei-2sv08.pdf>

Rhode Island: Bill enacted 14 July 2006 bans **PentaBDE and OctaBDE and required a study of decaBDE to be reported to the legislature.**

Deleted: 14,

Deleted: OctaBDE.

Formatted: Font color: Dark Blue

Washington<sup>7</sup>: 2004 Executive Order required Departments of Ecology, Health to develop actions state can take to reduce exposure to select PBDEs. The State of Washington has since released its PBDE Chemical Action Plan. **Legislation passed in 2007 bans pentaPBDE and OctaPBDE, with limited exceptions, by 2008; bans the use of decaBDE in mattresses by 2008; and bans the use of the decaBDE in televisions, computers, and residential upholstered furniture by 2011.**

## Canada

c-Octa BDE has never been produced in Canada (UNECE survey 2007, Canada). According to the draft report by Environment Canada, only small amounts of c-OctaBDE are imported. In Canada, results from a recent survey conducted for the year 2000 confirmed that c-OctaBDE is not manufactured in Canada. However, approximately 1300 tonnes of PBDEs (including c-OctaBDE) were imported into Canada in that year. (UNEP, 2007c Canada).

Canada published a scientific screening assessment on PBDEs on July 1, 2006. This assessment indicates that PBDEs, including all BDE congeners contained in c-OctaBDE, are toxic under section 64(a) of the Canadian Environmental Protection Act, 1999 (CEPA 1999). The report also recommends the implementation of virtual elimination for Tetra-, penta- and HexaBDEs which were found to be persistent, bioaccumulative, and present in the environment primarily as a result of human activity. PBDEs were added to Schedule 1 (List of Toxic Substances) to CEPA, (Canada Gazette, 2006b). Canada publicly released a proposed risk management strategy for addressing PBDEs in the Fall of 2006 which describes how the identified risks posed by the use and/or release of PBDEs will be addressed.

In December 2006, Canada published proposed Polybrominated Diphenyl Ethers Regulations for a formal 60 day public comment period. These Regulations prohibit the manufacture of seven PBDEs (TetraBDE, PentaBDE, HexaBDE, HeptaBDE, OctaBDE, nonaBDE and decaBDE) in Canada. The proposed regulations also prohibit the use, sale, offer for sale and import of TetraBDE, PentaBDE, HexaBDE and mixtures, polymers and resins containing these substances and prohibit the manufacture of these mixtures, polymers and resins. Comments have been received and are being reviewed. The prohibitions described will not be in effect until the Regulations are finalized. These Regulations represent an important first step in the risk management of PBDEs in Canada, with a focus on the three PBDEs that meet the criteria for virtual elimination under CEPA 1999.

Canada is developing additional risk management actions to complement the proposed regulations, specifically a regulation targeting PBDEs in manufactured products.

---

<sup>7</sup> Comment made by Canada (e-mail by Maya Berci from 25 May 2007): "This information is out of date, legislation that sets a North American precedent was recently passed in Washington State. House Bill 1024 was passed April 19, 2007 which prohibits manufacture, sale or distribution of most items containing PBDE as long as a safer alternative exists. The legislation calls for a ban on the manufacture and sale of mattresses containing PBDE effective January 1, 2008, and the manufacture and sale of televisions, computers and residential upholstered furniture containing PBDE by January 1, 2011, if a safer and technically feasible alternative is found. Wording to be checked with Washington State."

## Asia

There is no specific legislative control of OctaBDE in Japan (BSEF, 2006), although the Japanese Chemical Substances Control Law (CSCL) applies to **them**. Voluntary phase out of Penta- and OctaBDE by industry is underway in Japan.

**Comment [J5]:** Are you saying that the law applies generally to PBDEs? If so, then a simple statement saying this should be sufficient.

[According to the state of knowledge of the Bromine Science Environmental Forum, there is no existing **legislation** in the Asia-Pacific region restricting the use of any brominated flame retardants (BSEF, 2006).]

**Comment [J6]:** This claim is contradicted by the paragraph below describing legislation prohibiting PBDEs in China. This sentence should be deleted.

At the end of February 2006, China promulgated a law similar to the EU RoHS Directive. Substances targeted are the same as those targeted in the EU RoHS. Essentially, it will prohibit PentaBDE and OctaBDE use in new electric and electronic equipment when fully implemented. The implementation of phase 1 of the law is set for March 1, 2007; the implementation schedule for Phase 2 (full restrictions) is currently unclear but is expected to be implemented in a relatively short time frame, e.g. 1 year after Phase 1 (Canada Gazette, 2006a).

## International institutions

### The UNECE Convention on Long-range Transboundary Air Pollution

United Nations Economic Commission for Europe (UNECE) works for sustainable economic growth among its 55 member countries. The UNECE Convention on Long-range Transboundary Air Pollution requires Parties to endeavour to limit and, as far as possible, gradually reduce and prevent air pollution including long-range transboundary air pollution. The Convention has been extended by eight protocols. The Protocol for POPs focuses on a list of 16 substances that have been singled out according to agreed risk criteria for total ban, elimination at a later stage or restrictive use. In 2005, c-OctaBDE was nominated as a new POP to the Convention. In December 2005 c-OctaBDE was considered by the Executive Body of the Convention to meet the screening criteria for POPs. In 2006 the management options c-OctaBDE were assessed to give a basis for later negotiations on **restrictions**.

**Comment [J7]:** Anything else to add here? What were the management options?

### OSPAR Commission<sup>8</sup>

c-Octa-BDE, **and nonaBDE are** part of the list of substances of possible concern. According to BSEF (UNEP, 2007a BSEF), under the reviewed list, c-Octa-BDE is put under **section C** – about the substances put on hold because they are not produced and/or used in the OSPAR catchments or are used in sufficiently contained systems making a threat to the marine environment unlikely.

**Deleted:** is

**Comment [J8]:** A reference with web link is needed here to confirm. I could find no finalized list broken down into sections that actually lists the substances in each section, just references to BSEF's claim; a scientific document needs more than this

### Helsinki Commission (HELCOM)

The Baltic Marine Environment Protection Commission (HELCOM) has included OctaBDE on their list of substances and substance groups suspected to be highly relevant to the Baltic Sea and subjected to data and information collection from Contracting Parties.

### OECD (Organisation for Economic Cooperation and Development)

The bromine flame retardants industry signed a Voluntary Industry Commitment with OECD in 1995. In 2003, the industry was discussing a review of the commitment with OECD. The major global brominated flame retardant manufacturers committed (among other commitments) to

**Comment [J9]:** This describes a voluntary activity by the industry, not an activity by the OECD. Is the entire body of work performed by the OECD on PBDEs described by a voluntary industry activity? Did the industry actually comply with the commitment? If so, then why does a current formulation produced after the agreement contain 10 – 11 % hexaBDE? This section should be deleted if there is no actual information about actions of the OECD itself.

<sup>8</sup> The 1992 OSPAR Convention is the current instrument guiding international cooperation on the protection of the marine environment of the North-East Atlantic. It combined and up-dated the 1972 Oslo Convention on dumping waste at sea and the 1974 Paris Convention on land-based sources of marine pollution.

minimize levels of hexa- and lower brominated diphenyl oxide congeners in c-OctaBDE and also to provide data regarding various toxicity and environmental studies including studies on the safe disposal and recycling of products containing brominated flame retardants (BSEF, 2006).

## Production, use and releases

### 2.1 Levels and trends of production

#### Overall demand and production

The annual world-wide production of all commercial polybrominated diphenyl ethers was in 1994 estimated as 40,000 tonnes/year, which was broken down as 30,000 tonnes/year (i.e. 75%) of c-decaBDE, 6,000 tonnes/year (i.e. 15%) of c-OctaBDE and 4,000 tonnes/year (i.e. 10%) of c-PentaBDE (WHO 1994). It is likely that the production volumes have since decreased. More up to date figures are available for use volumes (see chapter 2.2).

Comment [J10]: Of which congener?

Information on production of PBDEs in general is given in the Environmental Health Criteria document on PBDEs (WHO 1994). In this report it is stated that in the early 1990s there were eight producers of PBDEs (commercial penta-, octa- or deca-) in the world, with one in the Netherlands, one in France, two in the United States, three in Japan and one in the United Kingdom. The same total number of manufacturers was reported by KEMI (1994), but production was also reported to occur in Israel as well.

According to the Bromine Science and Environmental Forum, c-OctaBDE is no longer produced in the EU, USA and Japan. Information about production in developing countries is sparse. Until 2004, production was situated in the Netherlands, France, USA, Japan, UK and Israel (UNEP 2007c, BSEF). Investigations showed that it is at present essentially impossible to buy c-OctaBDE at global level (Canada Gazette, 2006a).

Comment [J11]: Octa appears to be produced and sold in China by SinoBrom. See [http://www.sinobrom.cn/cgi/search-en.cgi?f=product\\_en+product\\_en\\_1\\_&id=401501&t=product\\_en\\_1\\_](http://www.sinobrom.cn/cgi/search-en.cgi?f=product_en+product_en_1_&id=401501&t=product_en_1_)

Deleted: the Pacific Rim

Deleted:

Deleted: and there is no information that it is produced

Comment [J12]: This may not be true. Octa appears to be produced and sold in China by SinoBrom. See [http://www.sinobrom.cn/cgi/search-en.cgi?f=product\\_en+product\\_en\\_1\\_&id=401501&t=product\\_en\\_1\\_](http://www.sinobrom.cn/cgi/search-en.cgi?f=product_en+product_en_1_&id=401501&t=product_en_1_)

Within the European Union, there were two reported producers of c-OctaBDEs in the EU IUCLID database in 1994. However, both companies stopped production within the EU (1996/1998).

The amount imported into the EU in 1999 was estimated as 450 tonnes/year as the substance itself, with around 1,350 tonnes/year imported in finished articles (European Commission 2003a). In the light of the legislative restrictions that are in place in the EU, import of c-OctaBDE as such or in articles is prohibited, since "import" is also considered as "placing on the market" in the EU legislation.

In the USA c-OctaBDE is subject to EPA's TSCA Inventory Update Reporting Rule, under which production and import information is periodically collected. For the 2002 reporting year, U.S. production of c-OctaBDE was estimated in the range of 450 to 4,500 tonnes (UNEP 2007c, USA). Production in the USA has since ceased. A voluntary phase out was complete before the end of 2004 (UNECE survey 2007, BSEF).

c-OctaBDE has never been produced in Canada (UNECE survey 2007, Canada). According to the draft report by Environment Canada only small amounts of c-OctaBDE are imported. In Canada, results from a recent survey conducted for the year 2000 confirmed that c-OctaBDE is not manufactured in Canada. However, approximately 1300 tonnes of PBDEs (including c-OctaBDE) were imported into Canada in that year. (UNEP, 2007c Canada 2).

## 2.2 Use of c-OctaBDE

### Use volumes

Arias (2001) reported that worldwide demand for c-OctaBDE was 3,825 tonnes/year in 1999. According to BSEF, the market demand for c-OctaBDE in 2001 was a comparable amount with 3,790 tonnes/year (UNEP, 2007c Canada 1) of which 40% are used in the Americas<sup>9</sup>, 16% in Europe<sup>10</sup>, 40% in Asia<sup>11</sup> and 4% in the rest of the world.

Within the EU, the placing on the market and use of c-OctaBDE was totally banned in 2003 (European Union, 2003). Before the ban, the combined import and production figure for the EU (i.e. the total EU consumption) of all PBDE flame retardants was 10,946 tonnes/year (in 1989) (WHO 1994).

In addition, it is possible that c-OctaBDE has been imported into or exported from the EU as a component of finished articles or master batch (polymer pellets containing additives). Reliable figures for likely quantities involved are not available. Manufacturers estimate that a figure of around 1,350 tonnes/year was realistic for the imports of c-OctaBDE into the EU in finished articles or master batch in 1999 (this figure then means that around 33% of the global amount of c-OctaBDE produced entered the EU either as c-OctaBDE itself or in finished or semifinished articles) (European Commission 2003a). Since the ban of c-OctaBDE in 2004 the import of articles containing c-OctaBDE into the EU is prohibited.

The UNECE survey (2007) has led to the following information on the use of c-OctaBDE in EU Member States:

- Belgium: the use of c-Octa-BDE has stopped; no information when;
- Czech Republic: c-OctaBDE has never been used;
- Cyprus: c-OctaBDE is not imported in Cyprus; no data is available on c-OctaBDE in imported products;
- Italy: according to industry statements use of c-OctaBDE has stopped since the 1980;
- Netherlands: use stopped in 2004;
- France: goods containing polyBDEs imported to France in 2004 cause imports of 133 tonnes of polyBDEs (including c-OctaBDE) to France. Volumes of exported polyBDE were negligible;
- United Kingdom: use of c-OctaBDE as flame retardant in polymer pellets and as flame retardant in finished products (wearing apparel, textiles, rubber and plastic products and furniture) stopped since 1997.

In Norway, a prohibition against production, import, export and the use of c-OctaBDE has been in place since 2004. It is also prohibited to produce, import, export or use products or flame retardant parts of products with over 0.1 % of BDE-196 by weight. An exception for use in evacuation equipment in aeroplanes ended 21 March 2006. Waste with a content of BDE-196 of 0.25 % or greater is treated as hazardous waste, for OctaBDE this means destruction. Recycling of articles

---

<sup>9</sup> All countries in North, South and Central America

<sup>10</sup> All countries in Eastern and Western Europe

<sup>11</sup> Australia, New Zealand and the Indian subcontinent

containing banned BFRs (Brominated Flame Retardants) is therefore only accepted, if the producers of the new product can guarantee that it will not contain BFRs (UNEP, 2008 Norway). **In 2008, Norway prohibited a ban on new products containing decaBDE leaving the transport sector as the only exemption.**

For Switzerland figures are available on the amount of c-OctaBDE still in use in plastics in electrical and electronic appliances but the use was declining. Since 2005 marketing and use of c-OctaBDE is prohibited. According to a substance flow analyses on the end of the 1990ies approximately 5.2 tonnes of c-OctaBDE have been imported for the use in domestic production of electric and electronic goods and approximately 36 tonnes have been imported in finished products. Consumption of c-OctaBDE in finished products is estimated to be 22 t/y. Preparations of c-OctaBDE are not used in Switzerland. About 60% of the 22 t c-OctaBDE which are used per year in consumer goods are used in electric and electronic goods, 40% in cars. During the past two decades a stock of 680 tonnes of OctaBDE in products has been accumulated in Switzerland. Currently this stock is reduced by 40 t/year. About 70% of the total c-OctaBDE stock of 680 t can be found in electric and electronic goods. The most important products for stocks and emissions are TVs (40%), cars (20%) and building materials such as plastic foils (10%; these do, however, not contain c-OctaBDE anymore). Exports were around 19 tonnes in finished products and 62 tonnes in solid waste (UNEP 2007c Switzerland; SAEFL 2002).

According to the Annex E response of Canada on c-OctaBDE (UNEP, 2007c Canada), a very small amount of c-OctaBDE was imported into Canada in 2000. The volumes reported do not include quantities imported in finished articles. According to Environment Canada (2006b), no ABS (main use type for OctaBDE flame retardant) is produced in Canada; however, Canadian imports of ABS terpolymers were 70.9 kt in 2000 and 66.2 kt in 2002. Of the 54 kt of ABS consumed in Canada in 1994, the major uses included pipes and fittings (50%), automotive parts (33%), business machines (7%), and appliances (7%). Information gathered through an Environment Canada use pattern survey in 2001 identified that c-OctaBDE was used in Canada in 2000. Significant reformulation activity has occurred in recent years. All companies that reported use of c-OctaBDE in 2000 reported minor remaining uses in 2005, and complete phase-out by 2006 (UNECE survey 2007, Canada).

According to BSEF, the use of c-OctaBDE as flame retardant in polymer pellets in the USA stopped in 2004 and there are no more stockpiles present (UNECE survey 2007, BSEF). According to the US-EPA, production, not use, was phased out in the USA. However US-EPA expects, that levels of the stockpiles will decrease over time (UNECE survey 2007, USA).

**Comment [J13]:** These two sentences are contradictory: BSEF says no stockpiles, US EPA says there are stockpiles that will decrease.

No use is reported from Turkey and Mauritius (UNEP, 2007c).

Watanabe and Tatsukawa (1990) reported that around 1 000 tonnes of c-OctaBDE were used in Japan in 1987. Use in Japan has declined from 1,100 tonnes in 1992 to 3 tonnes in 2002 (UNEP, 2007c Japan).

### Use types

Polybrominated diphenyl ethers in general are used as flame retardants. They are mostly used in applications in the plastics and textile industries. Historically about 70 per cent of c-OctaBDE had been used in ABS polymers. Other minor uses included HIPS, PBT and polyamide polymers. c-OctaBDE was mainly used as flame retardant in ABS type plastics which were used in consumer and commercial electronics and office equipment (UNEP, 2008 BSEF). As is common with BFRs in general, a synergist is also added (frequently antimony trioxide) to increase the overall effectiveness of the flame retardant treatment. PBDEs are flame retardants of the additive type, i.e. they are physically combined with the material being treated rather than chemically combined (as in

reactive flame retardants). This means that there is the **likely** possibility that the flame retardant may diffuse out of the treated material to some extent.

The amount of flame retardant used in any given application depends on a number of factors such as the flame retardancy required of the finished product, the effectiveness of the flame retardant and synergist within a given polymer, the physical properties of the end product e.g. colour, density, stability etc.) and the use to which the end product will be put. Typically, the flame retardants are added at concentrations between 5 and 30% by weight (WHO 1994). Further information provided by industry indicates that c-OctaBDE is always used in conjunction with antimony trioxide. In the EU, it was primarily used in ABS polymers at 12-18% weight loadings in the final product (European Commission, 2003a). Globally, 70% of c-OctaBDE has been added to ABS polymers (Environment Canada, 2006b)

The main type of use indicated in the Annex E responses in 2007 is the use in ABS polymers. According to the European Union Risk Assessment Report (European Commission, 2003a), around 95% of the total c-OctaBDE supplied in the EU was used in ABS. Other minor uses, accounting for the remaining 5% use, included HIPS, PBT and polyamide polymers, at typical loadings of 12-15% weight in the final product. In some applications, the flame retardant is compounded with the polymer to produce pellets (masterbatch) with slightly higher loadings of flame retardant. These are then used in the polymer processing step to produce products with similar loadings as given above.

The flame retarded polymer products are typically used for the housings of office equipment and business machines. Other uses that have been reported for c-OctaBDE include nylon and low density polyethylene (WHO, 1994), polycarbonate, phenol-formaldehyde resins and unsaturated polyesters (OECD, 1994) and in adhesives and coatings (WHO, 1994).

### **2.3 Global demand in the future**

The annual world-wide production of c-OctaBDE was about 6,000 tonnes/year in 1994. The production volumes have since decreased to about 3,800 tonnes/year in 2001. Considering a value of 3.6 €/kg this corresponded to a global market value of 13.7 m€. Due to the phase out of production in the USA, first voluntary phase out activities in Asia (Japan) and marketing and use restrictions in the EU, Norway and Switzerland and an already significantly increased use of alternatives (UBA, 2003b) it can be assumed that the demand has already further decreased and will continue to do so.

### **2.4 Emissions from production and processing**

The European Union Risk Assessment on c-OctaBDE (European Commission, 2003a) contains release estimates from production, handling, compounding and conversion (processing), use of products, disposal and recycling and dismantling. Table 2 and Table 3 give an overview on estimated releases of c-OctaBDE based on the European Union Risk Assessment for 1994 and 1999 use volumes respectively. Due to the ban of c-Octa BDE in the EU the actual releases from production, handling, compounding and conversion are considered to be zero **in the EU**.

Table 2: Overview on estimated releases of OctaBDE based on the European Union Risk Assessment (European Commission, 2003a) for 1994 use volumes<sup>12</sup>

Emissions/releases from	1994 (tonnes/year)				
	to air	to water	to wastewater	to waste	to soil
Production					
Handling				5.4	
compounding and conversion	1.28		1.28		
use of products	0.0557	13.9			41.8
Disposal				2480	
Recycling and dismantling					
EU total per medium	1.3357	13.9	1.28	2485.4	41.8
EU total	<b>2543.7157</b>				

Table 3: Overview on estimated releases of OctaBDE based on the European Union Risk Assessment (European Commission, 2003a) for 1999 use volumes.

Emissions/releases from	1999 (tonnes/year)				
	to air	to water	to wastewater	to waste	to soil
Production					
Handling				0.945	
compounding and conversion	0.225		0.225		
use of products	0.0269	6.69			20.2
Disposal				1316	
Recycling and dismantling					
EU total per medium	0.2519	6.69	0.225	1316.945	20.2

<sup>12</sup> Note: The figures diverge from the summary figures in the European Union Risk Assessment (see European Commission, 2003a, Table 3.1, Summary of estimated releases of octabromodiphenyl ether to the environment) as the release is indicated for the EU as a total and not for the continental model. To present results for the continental model figures would have to be reduced by 10%.

EU total	<b>1344.3119</b>
----------	------------------

As there is no production of c-Octa BDE in the EU , Switzerland, Norway, Canada and the USA, releases from production are considered zero for the Europe and North America. **Information about c-OctaBDE production from developing countries is sparse.**

Releases from polymer processing sites may arise during handling and compounding and conversion. Due to marketing and use restrictions, there is currently no compounding and conversion of c-Octa BDE in the EU.

In Canada releases have been estimated for historic polymer processing in the year 2000. Releases of c-OctaBDE to solid waste/water and air were estimated to be very low, at 0.03 tons/year and 0.01 tons/year respectively from compounding and conversion processes (unpublished internal report, Environment Canada, 2003). Processing of c-OctaBDE has stopped in Canada since 2006 (UNECE survey 2007, Canada).

Table 4: Estimated releases from historic use in 2000 (UNEP, 2008 Canada)

Source of Release	Release (ton/year)	Compartment of release (air, water, soil)
Materials Handling - removal from drums/sacks, pouring etc.	0.4	liquid waste
Compounding -formulation into resin, simple mixing; and Conversion – open process: foam articles	0.03 (0.023 from compounding + 0.010 from conversion)	Soil
Compounding - formulation into resin, simple mixing; and Conversion – open process: foam articles	0.01 (0.002 from compounding; + 0.02 0.010 from conversion)	Air
Emissions from OctaBDE from plastic products in service	0.7	Air
Emissions from OctaBDE from ABS products at disposal	>3.09 tons/year, with >150.97 tons per year remaining in the disposed products	solid waste/water

Releases from current processing are considered zero in the EU and Canada.

As in the USA production of c-OctaBDE (not use) was phased out there may still some releases be expected from processing. It is assumed that levels of any existing stockpiles will decrease over time and it can be expected that releases from processing will correspondingly decrease. However the processing of imported c-OctaBDE in polymer pellets cannot be completely ruled out.

According to Annex E responses 2007 from Germany and BSEF (UNEP, 2007c), c-OctaBDE releases may occur when applying flame retardant treatments to textiles. In France OctaBDE was measured in waste waters of seven out of 667 so called "classified plants for environment protection". Five out of these seven plants dealt with textile treatment (UNECE survey 2007, INERIS 2006).

**Deleted:** To conclude, still remaining releases from processing of c-OctaBDE in the USA are considered to be zero or close to zero with decreasing trend.¶

**The commercial octaBDE mixture, DE79 also contains both polybrominated biphenyls (PBB) and polybrominated dibenzofurans (PBDF) which are also present in other commercial PBDE mixtures such as DE-71 and DE-83.<sup>13</sup> Using production / usage estimates of commercial PBDE mixtures in 2001, potential global annual emissions of PBB and PBDF resulting from the use of PBDEs were calculated to be 40 kg and 2300 kg respectively.**

General process and release descriptions, and exposure estimates for OctaBDE are available in an April 2003 risk assessment conducted by an industry sponsor under US EPA's Voluntary Children's Chemical Evaluation Program (US EPA, 2003b; UNECE survey 2007, USA). The study contains no information on amounts released from production, handling, use, waste or recycling/recovery.

**Comment [J14]:** If the document lacks these things, it does not seem useful to cite it or include it. This paragraph should be deleted.

## **2.5 Emissions from handling and transport**

Releases from polymer processing sites may arise during handling of c-OctaBDE containing polymer raw material. Losses of powders during the handling of raw materials have been estimated as 0.21% for powders of particle size >40 µm. These losses will initially be to the atmosphere, but it is expected that the dust will rapidly settle and so losses will be mainly to solid waste, which may be recycled or disposed of, or washed to wastewater (European Commission, 2003a).

In the EU and Canada handling of polymer pellets containing c-OctaBDE does not occur at present.

In Canada the release estimate for the year 2000 from historic handling (materials handling - removal from drums/sacks, pouring etc.) was 0.36 tonnes/year to solid waste/water. Processing of c-OctaBDE has stopped in Canada since 2006 (UNECE survey 2007, Canada).

In the USA handling of polymer pellets containing c-OctaBDE has already ceased or is very limited and is expected to decrease over time.

## **2.6 Emissions from the use of products containing c-OctaBDE**

In the light of the ban and phase out of c-OctaBDE, it is important to focus on the fate in products (ECE EB, 2006). Emissions of c-OctaBDE occur from volatile and leaching losses over the service life of polymers or textiles, and also particulate losses over their service life and at disposal. In practise it is expected that total emissions will be dominated by volatile losses from polymers over their service life (e.g. >91% of the total emission of c-OctaBDE to air).

### **Volatilisation**

According to the European Union Risk Assessment (European Commission, 2003a) the loss during the service life of a product will be 0.54% (assuming a life of 10 years). The available information for 1999 indicates that the amount of c-OctaBDE present in finished articles in the EU could be around 1,350 tonnes/year (the estimate includes both articles manufactured in the EU and imported articles containing c-OctaBDE). This corresponds to a loss of 0.73 tonnes/year in the EU, based on the 1999 EU consumption figure of 1,350 tonnes/year. These figures overestimate the current EU usage of c-OctaBDE but, as a result, **may** account to some extent for the (unquantifiable) amount of c-OctaBDE that may be imported into (or exported from) the EU in finished articles or masterbatch. The losses will initially enter the atmosphere. It should be born in mind that since the products may

**Deleted:** will also

<sup>13</sup> Hanari N, Kannan K, Miyake Y, Okazawa T, Kodavanti PR, Aldous KM, Yamashita N (2006) Occurrence of polybrominated biphenyls, polybrominated dibenzo-p-dioxins, and polybrominated dibenzofurans as impurities in commercial polybrominated diphenyl ether mixtures, *Environ Sci Technol* 40:4400-4405

be used over a 10 year lifetime or longer, and that each year new products containing c-OctaBDE are likely to enter into use during this time, the actual amount of c-OctaBDE present in plastic products, and hence potentially released, could be around 10 times the amount estimated above. The estimated amount of volatile losses in the EU from products in service life is therefore 7.29 tonnes/year using the 1999 data.

According to estimations for Canada the estimated amount of volatile losses from products in service life is 0.6 tonnes<sup>14</sup> per year for the year 2000 (UNECE survey 2007, Canada). Extrapolating the Canadian estimation in an analogous way to the use figures for all countries in North, South and Central America for 2001 result in an estimated amount of volatile losses from products in service life of 0.86 tonnes per year for this region in 2001.

## Leaching

### “Waste remaining in the environment”

“Waste remaining in the environment” can be considered to be particles (or dust) of polymer product, or dust generated from polymer products that contain c-OctaBDE. These particles are primarily released to the urban/industrial soil compartment, but may also end up in sediment or air. End-products with outdoor uses are most likely to be sources of this type of waste, where releases can occur over the lifetime of the product due to weathering and wear.

**Increasing attention has focused on the release of OctaBDE and other PBDEs to dust in the indoor environment.<sup>15 16 17 18 19 20 21</sup> Keeping consumer products containing octaBDE and other PBDEs for many years in the home and office has the potential to be a long-term exposure source and human body burdens of PBDEs have been associated with house dust**

**Comment [J15]:** This is dealt with in the section below and should be deleted. The release of PBDEs during use is well documented in the scientific literature. The remark about release to water is disingenuous since the EU Commission determined substantial fractions ending up in surface water.

**Deleted:** Given that the major use of plastics containing c-OctaBDE appears to be in electrical applications and that the substance has very low water solubility, the potential for leaching of c-OctaBDE from the products during use appears to be small.

**Deleted:**

<sup>14</sup> Estimated based on an emission factor of 0.054% per annum, and a vapour pressure of 4.9 E -8 mm Hg at 20°C, and 1223.22 tons estimated market demand for OctaBDE in plastics in Canada in 2000

<sup>15</sup> Wilford BH, Shoeib M, Harner T, Zhu J, Jones KC (2005) Polybrominated diphenyl ethers in indoor dust in Ottawa, Canada: implications for sources and exposure Environ Sci Technol 39:7027-7035

<sup>16</sup> Blake A, McPherson A, Thorpe B (2004) Brominated flame retardants in dust on computers: The case for safer chemicals and better computer design, Clean Production Action and Computer Take Back Campaign

<sup>17</sup> Santillo D, Labunska I, Davidson H, Johnston P, Strutt M, Knowles O (2003) Consuming chemicals: Hazardous chemicals in house dust as an indicator of chemical exposure in the home, Greenpeace Research Laboratories, Department of Biological Sciences, University of Exeter, UK

<sup>18</sup> Stapleton HM, Dodder NG, Offenberg JH, Schantz MM, Wise SA (2006) Polybrominated diphenyl ethers in house dust and clothes dryer lint, Environ Sci Technol 39:925-931

<sup>19</sup> Betts KS (2008) Unwelcome guest: PBDEs in indoor dust, Environ Health Perspect 116 <http://www.ehponline.org/members/2008/116-5/focus.html>

<sup>20</sup> Allen JG, McClean MD, Stapleton HM, Nelson JW, Webster TF (2007) Personal exposure to polybrominated diphenyl ethers (PBDEs) in residential indoor air, Environ Sci Technol 41:4574-4579

<sup>21</sup> **Allen JG, McClean MD, Stapleton HM, Webster TF (2008) Critical factors in assessing exposure to PBDEs via house dust, Environ Int May 2008 in press**

concentrations.<sup>22</sup> Recent research indicates that hexaBDE and other BDEs in dust are available and biologically active.<sup>23</sup>

In addition, releases of this type can occur from disposal processes, particularly where articles are dismantled or subject to other mechanical processes, regardless of the method of ultimate disposal (or recycling/recovery). Air and dust monitoring data at dismantling plants confirm that this is a source of release of polybrominated diphenyl ethers (European Commission, 2003).

At present there is no agreed methodology given in the Technical Guidance Document (European Commission 2003b) for assessing the risks from this type of waste. However, a methodology was outlined in the draft risk assessment report for di-(2-ethylhexyl)phthalate (DEHP) (European Commission, 2000) and a similar approach is taken in the European Union Risk Assessment (European Commission, 2003a). The release estimates obtained show a high degree of uncertainty.

According to this approach the amount of “waste remaining in the environment” for the EU in 1999 can therefore tentatively be estimated as indicated in Table 5:

Table 5: Release estimates during service life and disposal of products containing c-OctaBDE for the EU in 1999

	1999 data
Total amount of octabromodiphenyl ether present in polymers	1,350 tonnes/year
Amount lost through volatilisation over the service life	7.29 tonnes/year
Total amount remaining in plastics	1,343 tonnes/year
Estimated fraction of plastic used for outdoor applications	0.1%
Amount of in plastic used for outdoor applications	1.34 tonnes/year
Estimated loss as “waste remaining in the environment”	2% over lifetime
Emission as “waste remaining in the environment” over lifetime	0.027 tonnes/year
Total amount remaining in plastics at disposal	1,343 tonnes/year
Estimated loss as “waste remaining in the environment” at disposal	2%
Emission at disposal	26.86 tonnes/year
Amount remaining in plastics for disposal (or recycling)	1,316 tonnes/year

<sup>22</sup> Wu N, Herrmann T, Paepke O, Tickner J, Hale R, Harvey LE, La Guardia M, McClean MD, Webster TF (2007) Human exposure to PBDEs: associations of PBDE body burdens with food consumption and house dust concentrations, *Environ Sci Technol* 41:1584-1589.

<sup>23</sup> Huwe JK, Hakk H, Smith DJ, Diliberto JJ, Richardson V, Stapleton HM, Birnbaum LS (2008) Comparative absorption and bioaccumulation of polybrominated diphenyl ethers following ingestion via dust and oil in male rats, *Environ Sci Technol* 42:2694-2700

Deleted: ¶

As indicated in the table the estimated amount of “waste remaining in the environment” in the EU, which is particularly related to waste treatment at disposal, is 26.9 tonnes/year (26.86 tonnes per year from disposal + 0.027 tonnes per year from product lifetime) for the EU in 1999. According to the European Union Risk Assessment it has been assumed that these releases enter industrial/urban soil (~75%), air (~0.1%) and surface water (~24.9%).

For Canada releases have been estimated for the year 2000. The estimated amount of emissions of c-OctaBDE from ABS products at disposal will exceed 2.8 tonnes per year<sup>24</sup>, with >137 tonnes per year remaining in the disposed products (UNECE survey 2007, Canada).

Extrapolating the Canadian estimation in an analogous way to the use figures for all countries in North, South and Central America for 2001 i.e. approximately 1,500 tonnes per year this would result in an amount of waste remaining in the environment of approximately 3.5 tonnes per year from disposal.

Consequently as current products reach the end of their service life, proper management of this waste will eliminate service life losses **to the indoor and outdoor environments** over the coming years.

## 2.7 Emissions from waste containing c-OctaBDE

### Emissions at disposal

In addition to the “waste remaining in the environment” during the service life of a product a second fraction of “waste remaining in the environment” occurs at disposal. These emissions at disposal are already covered in the release estimates during the service life of a product.

### Emissions after disposal

According to the European Union Risk Assessment (European Commission, 2003a), emission of c-OctaBDE also occurs after disposal.

In a Swiss study (SAEFL 2002) a substance flow analysis of c-OctaBDE has been performed for Switzerland. During the past two decades a stock of 680 tonnes of OctaBDE in products has been accumulated in Switzerland. Currently this stock is **reduced** by 40 t/year. With respect to the fate of c-OctaBDE in waste the study shows that c-OctaBDE usually enters the solid waste stream.

Common pathways for disposal and elimination are incineration, landfilling and export (which amounted in Switzerland according to the study to approximately 86%, 10% and 4% respectively). Comparable pathways and possibly also relations might be extrapolated to other countries in the UNECE region as well. Assuming that an amount of 1,350 t of c-OctaBDE is placed on the EU market in products each year and an average product lifetime of 10 years leads to a rough estimation of a stock of c-OctaBDE of 13,500 tonnes in products in the EU. Assuming that since 2005 no more c-OctaBDE containing products entered the market, the current stock can be roughly estimated to amount to approximately 9,450 tonnes (in 2007).

**Comment [J16]:** Does this mean that this amount enters the environment?

Plastics containing c-OctaBDE will usually be disposed of either to landfill or by incineration. It is expected that emissions **of PBDEs** from **state of the art** incineration processes will be near zero, although the question of formation of brominated dibenzofurans and dibenzo-p-dioxins (**PBDD/F**) has been raised as a potential problem. According to SAEFL 2002 the destruction efficiency of c-OctaBDE in incineration was estimated 99.9% with the remainder of 0.1% being mainly disposed of to landfill.

<sup>24</sup> Estimated based on a loss to the environment of approx 2% of the quantity disposed

When plastic containing c-OctaBDE is disposed of to landfill, in theory it could volatilise to the atmosphere or leach out of the plastic and groundwater.

Using the assumption that the amount of plastic containing c-OctaBDE produced each year replaces that disposed of each year the amount of c-OctaBDE disposed of in plastic articles could be around 1,316 tonnes/year for the EU based on the 1999 consumption data.

[No experiments appear to have been carried out on the leachability of c-OctaBDE from polymers in landfills, but, by comparison with the decaBDE (see the risk assessment report of decaBDE (European Commission, 2002)), it would not be expected to leach to a significant extent from polymers, unless the polymer itself undergoes some form of degradation. In addition, c-OctaBDE is likely to adsorb strongly onto soil which **would** significantly lower its leaching potential from landfills into groundwater. Similarly, the low vapour pressure of the substance would limit its volatility from landfills. In addition, **direct** release to the environment of volatilised c-OctaBDE is **likely to be** very limited due to the coverage of landfills and the capture and treatment of waste gas from landfills.]

**Comment [J17]:** This paragraph should be deleted/ re-written; see the references below and a proposed paragraph below this one.

See Chemosphere (2006) 65: 506 – 513; Leaching characteristics of polybrominated diphenyl ethers (PBDEs) from flame-retardant plastics

See also: Chemosphere (2004) Leaching of brominated flame retardants in leachate from landfills in Japan Chemosphere 57:1571-1579

Deleted: will

#### Proposed paragraph to replace the one above:

**PBDEs are released to water from raw landfill leachate and leaching is enhanced by humic acid.<sup>25 26</sup> Analysis of a landfill in Japan revealed significant PBDE concentrations below heptaBDE in the leachate.<sup>27</sup> PBDEs were also detected in an analysis of landfill leachates in South Africa and the authors expressed concern that the compounds could infiltrate groundwater around the sites since the landfills were not adequately lined.<sup>28</sup> A study by the Minnesota Pollution Control Agency (USA) revealed pentaBDE, hexaBDE, nonaBDE and decaBDE accumulation in landfill leachate from five landfills including municipal, industrial, and demolition landfills with decaBDE accounting for the highest percentage of total PBDE concentrations.<sup>29</sup>**

To conclude, releases after disposal, if handled correctly and by applying BAT and BEP, **may** be considered to be **low, however, due to conditions in different countries and the current lack of knowledge, the possible long-term increase in levels as a result of releases from waste sites may need to be considered further (European Commission 2003).**

Deleted: can

Deleted: negligible

Formatted: Font: Bold

#### Emissions from sewage sludge

**C-OctaBDE and other PBDEs are released from waste water treatment facilities and can be measured in aquatic organisms.<sup>30 31 32 33 34 35 36</sup> Land application of sewage sludge**

<sup>25</sup> Osako M, Kim Y, Sakai S (2004) Leaching of brominated flame retardants in leachate from landfills in Japan, Chemosphere 57:1571-1579

<sup>26</sup> Kim Y, Osako M (2006) Sakai S Leaching characteristics of polybrominated diphenyl ethers (PBDEs) from flame-retardant plastics, Chemosphere 65:506-513

<sup>27</sup> Kim Y, Osako M (2006) Sakai S Leaching characteristics of polybrominated diphenyl ethers (PBDEs) from flame-retardant plastics, Chemosphere 65:506-513

<sup>28</sup> Odusanya DO, Okonkwo JO, Botha B (2008) Polybrominated diphenyl ethers (PBDEs) in leachates from selected landfill sites in South Africa, Waste Management April 2008 in press

<sup>29</sup> Fardin O, (2005) Flame retardants: polybrominated diphenyl ethers (PBDEs), Minnesota Pollution Control Agency <http://www.pca.state.mn.us/publications/reports/tdr-g1-02.pdf>

<sup>30</sup> Gevao B, Muzaini S, Helaleh M (2008) Occurrence and concentrations of polybrominated diphenyl ethers in sewage sludge from three wastewater treatment plants in Kuwait, Chemosphere 71:242-247

<sup>31</sup> Wang Y, Li X, Wang T, Zhang Q, Wang P, Fu J, Jiang G (2007) Effect of municipal sewage treatment plant effluent on bioaccumulation of polychlorinated biphenyls and polybrominated diphenyl ethers in the recipient water, Environ Sci Technol 31:6026-6-32

Formatted: Comment Text

Formatted: English (U.S.)

Formatted: English (U.S.)

Formatted: English (U.S.)

Formatted: English (U.S.)

contaminated with c-octaBDE and other PBDEs leads to their release into soils and subsequent uptake by earthworms presenting an exposure pathway into the terrestrial food chain.<sup>37 38</sup>

### Emissions from recycling and dismantling

Volatile and/or particulate emissions of c-OctaBDE occur during recycling/recovery and dismantling, particularly where articles are dismantled or subject to other mechanical processes, regardless of the method of ultimate disposal (or recycling). These emissions can be allocated to emissions at disposal and are already covered in the release estimates during the service life of a product.

Air and dust monitoring data at dismantling plants confirm that this is a source of release of polybrominated diphenyl ethers (European Commission, 2003).<sup>39</sup> According to the European Union Risk Assessment the estimated loss as “waste remaining in the environment” at disposal is estimated to be 2% of the total amount of c-OctaBDE that is contained in products at the end of their service life. **In addition the formation of brominated dibenzofurans and dibenzo-p-dioxins (PBDD/F) has been raised as a potential problem at dismantling plants. Severe PBDD/F and PCDD/F emissions have been observed in air near electronic waste dismantling areas in China.**<sup>40</sup> **Surface soils near dismantling and recycling sites have also been found to contain octaBDE, PCDD/Fs, and other PBDEs.**<sup>41</sup>

Deleted: ¶

In the European Union Risk Assessment (European Commission, 2003) it has been assumed that this release is distributed to industrial/urban soil (75%), air (0.01%) and surface water (24.9%).

### 2bis Debromination

#### Background

<sup>32</sup> Wang Y, Zhang Q, Lv J, Li A, Liu H, Li G, Jiang G (2007) Polybrominated diphenyl ethers and organochlorine pesticides in sewage sludge of wastewater treatment plants in China, *Chemosphere* 68:1683-1691

<sup>33</sup> Knoth W, Mann W, Meyer R, Nebhuth J (2007) Polybrominated diphenyl ether in sewage sludge in Germany, *Chemosphere* 67:1831-1837

<sup>34</sup> Hale RC, La Guardia MJ, Harvey E, Gaylor MO, Mainor TM (2006) Brominated flame retardant concentrations and trends in abiotic media, *Chemosphere* 64:181-186

<sup>35</sup> Anderson T, MacRae JD (2006) Polybrominated diphenyl ethers in fish and wastewater samples from an area of the Penobscot River in central Maine, *Chemosphere* 62:1153-1160

<sup>36</sup> North KD (2004) Tracking polybrominated diphenyl ether releases in a wastewater treatment plant effluent, Palo Alto, California, *Environ Sci Technol* 38:4484-4488

<sup>37</sup> Eljarrat E, Marsh G, Labandeira A, Barcelo D (2008) Effect of sewage sludges contaminated with polybrominated diphenyl ethers on agricultural soils, *Chemosphere* 71: 1079-1086

<sup>38</sup> Sellstrom U, de Wit CA, Lundgren N, Tysklind M (2005) Effect of sewage-sludge application on concentrations of higher-brominated diphenyl ethers in soils and earthworms, *Environ Sci Technol* 39:9064-9070

<sup>39</sup> Morf LS, Tremp J, Gloor R, Huber Y, Stengele M, Zennegg M (2005) Brominated flame retardants in waste electrical and electronic equipment: substance flows in a recycling plant, *Environ Sci Technol* 39:8691-8699

<sup>40</sup> Li H, Yu L, Sheng G, Fu J, Peng P (2007) Severe PCDD/F and PBDD/F pollution in air around an electronic dismantling area in China, *Environ Sci Technol* 41:5641-5646

<sup>41</sup> Leung AO, Luksemburg WJ, Wong AS, Wong MH (2007) Spatial distribution of polybrominated diphenyl ethers and polychlorinated dibenzo-p-dioxins and dibenzofurans in soil and combusted residue at Guiyu, an electronic waste recycling site in southeast China, *Environ Sci Technol* 41 :2730-2737

Formatted: English (U.K.)

The Risk Profile for c-OctaBDE (UNEP, 2007a) concluded that c-OctaBDE is a mixture of components with different properties and profiles, which may also be released to the environment due to its presence as components of other PBDE commercial products and also produced in the environment by debromination of commercial DecaBDE. The Risk Profile notes that the lower than expected bioaccumulation potential of HeptaBDE, OctaBDE, and NonaBDE may be due to debromination and subsequent formation of bioaccumulative PBDEs. In addition, the Risk Profile observes that the potential for long range transport has been observed for DecaBDE and that the lack of confirmation for Octa and NonaBDE may be related to the lower relative contribution and/or metabolism via debromination.

Photodecomposition, anaerobic degradation, and metabolism in biota are pathways of debromination that could produce other PBDEs with higher toxicity and bioaccumulation potential (UNEP, 2007a).

#### Photodecomposition

The photodecomposition of several BDEs has been studied in different matrices such as ethanol/water 80:20 (Eriksson *et al.* (2001))<sup>1</sup>, methanol/water 80:20 under UV light in the sunlight region (Eriksson *et al.* (2004))<sup>2</sup>; in a sealed polyethylene tube exposed to natural sunlight for up to 120 min (Peterman *et al.* (2003)); in hexane under UV light in the sunlight region (Fang L *et al.* (2008))<sup>3</sup> (Bezares-Cruz *et al.* (2004))<sup>4</sup>; in toluene, silica gel, sand, sediment and soil using artificial sunlight and on natural matrices of sediment, soil, and sand using natural sunlight (Soderstrom *et al.* (2004))<sup>5</sup> or water (Sanchez-Prado *et al.* (2006)).<sup>6</sup> NonaBDEs to triBDEs were formed in these studies and some also detected polybrominated dibenzo furans. In general, degradation was faster for the higher brominated congeners than for the lower brominated congeners. Half lives on natural matrices such as sediment, soil, and sand ranged between 40 and 200 hours (Soderstrom *et al.* (2004). Rayne *et al.* (2006)<sup>7</sup> suggest a short photochemical half-life for the hexa- BDE (BDE-153) in aquatic systems, with rapid reductive photodebromination to some of the most prevalent penta- and tetra-brominated diphenyl ether congeners.

Stapleton *et al.* (2008)<sup>8</sup> investigated the degradation potential of decaBDE in house dust using both natural and BDE-209-spiked dust material. Degradation of BDE 209 was observed in both matrices but was 35% greater in the spiked dust relative to the natural dust material. Debrominated products detected in the spiked dust included all three nonaBDEs (BDE 206, BDE 207, and BDE 208) and several octaBDEs (BDE 196, BDE 197, BDE 201, BDE 202, and BDE 203/200). The results suggest the potential for reductive debromination indoors. Another recent study of BDEs also found markers of decaBDE debromination (BDE202) in house dust (Allen *et al.* 2008).<sup>9</sup>

#### Anaerobic and microbial debromination

Anaerobic and microbial debromination has been studied in several different systems. The first report of reductive debromination of deca-BDE (BDE-209) was that of Gerecke *et al.* (2005)<sup>10</sup> who incubated it with sewage sludge to which certain primers (organic chemicals) had been added, over a period of 238 days. The concentration of BDE-209 was reduced by 30%, and octa- BDEs and the nona-BDEs BDE-207 and BDE-208 were formed, accounting for about 17% of the quantity lost, but a complete mass balance was not performed. Bromines were removed mainly from positions *meta*- and *para*-to the oxygen. In separate experiments, the nona-BDEs BDE-207 and BDE-206 were incubated and were degraded to mixtures of octa-BDEs.

The great variety of possible results is suggested by the highly selective reductive microbial debrominations observed in experiments reported by He *et al.* (2006).<sup>11</sup> Hepta- and Octa-BDE congeners were produced in cultures of *Sulfurospirillum multivorans* that was known to convert tetrachloroethylene to dichloroethylene, when decaBDE was exposed to it for two months. OctaBDE was not attacked in a similar system. Cultures of an alternative organism, *Dehalococcoides sp.*, failed to attack the decaBDE but an octaDBE mixture was extensively changed, over six months yielding a mixture of hepta- through di-BDEs which included the pentaBDE, BDE-99. Tetra-BDEs were formed over longer periods. Complete quantitation was not achieved and best results were obtained with certain strains of the organism especially when grown in the presence of trichloroethylene.

In an industry-funded study, Schaefer and Flaggs (2001)<sup>12</sup> exposed <sup>14</sup>C-labelled BDE-47 (a tetraBDE) to anaerobic sediments for 32 weeks and found that <1% of the total radioactivity was recovered as <sup>14</sup>CO<sub>2</sub> and <sup>14</sup>CH<sub>4</sub>, indicating that essentially no mineralization had occurred. They concluded that BDE-47 has the potential to degrade very slowly under anaerobic conditions. Schaefer and Flaggs (2001a)<sup>13</sup> performed a similar study of decaBDE for the bromine industry and concluded that the presence of deca-BDE in the environment does not contribute to environmental levels of penta-BDE. A critique by US EPA (Auer (2006)<sup>14</sup> noted that the intra- or extra-cellular nature of the debromination process was not identified, and that given the low water solubility of deca-BDE the incubation time of 32 weeks 'may be inadequate to represent environmentally realistic sediment residue times as well as to demonstrate debromination'.

#### Debromination in biota

In experiments reported by Stapleton *et al.* (2004)<sup>15</sup>, carp were fed for 62 days with food spiked with individual BDE congeners, and tissue and excreta were examined. At least 9.5±0.8% of BDE-99 in the gut was reductively debrominated to BDE-47 (one less bromine) and assimilated in carp tissues. Similarly, 17% of the heptabromo congener BDE-183 was reductively debrominated to hexabromo congeners.

Tomy *et al.* (2004)<sup>16</sup> exposed juvenile lake trout (*Salvelinus namaycush*) to three dietary concentrations of 13 BDE congeners (3-10 bromine atoms) in the laboratory for 56 days, followed by 112 days of clean food. Half-lives ( $t_{1/2}$ ) for some BDE congeners (e.g., BDE-85 and -190) were much lower than expected based on their Kow, whereas  $t_{1/2}$  of other BDE congeners (e.g., BDE-66, -77, -153, and -154) were much longer than anticipated based on Kow. This was explained by reductive debromination. The detection of three BDE congeners (BDE-140 plus an unknown penta-BDE, and an unknown hexa-BDE) in the fish, substances that were not present in the food or in the control fish, provided further evidence for the reductive debromination of BDEs.

Experiments involving whole animals have been less common, but when mice were treated orally and subcutaneously for 34 days with a commercial penta-BDE mixture (DE-71) (Qiu *et al.* (2007))<sup>17</sup> the recovered products were bromophenols and hydroxylated bromodiphenyl ethers. The recovered bromo-compounds were only a small proportion of the quantity of the original mixture administered to the animals.

When PBDEs, mainly deca-BDE (BDE-209), were fed to cows the congener array in the feces was the same as that in the feed, indicating that no changes took place in the rumen. (Kierkegaard *et al.*, 2007).<sup>18</sup> Other tissues, including the milk fat were enriched in BDE-207, -196, -197 and -182, and the authors interpret this as evidence that metabolic reductive debromination of BDE-209 occurs in other body tissues. Due to the experimental procedures

adopted, it was not possible quantitatively to assess the mass balance of dietary absorption. The authors cite work of Viberg *et al.* (2003)<sup>19</sup> who suggested that neurobehavioural changes observed in neonatal mice treated with BDE-209 were due to its transformation *in vivo* to more toxic lower congeners or to hydroxylated metabolites.

Van den Steen *et al.* (2007)<sup>20</sup> used silastic implants to expose European starlings (*Sturnus vulgaris*) to deca-BDE (BDE-209) and found octa- (BDE-196, BDE-197) and nonaBDEs (BDE-206, BDE-207, BDE-208) in muscle and liver in addition to deca-BDE, resulting in the first indications of debromination in birds.

La Guardia *et al.* (2007)<sup>21</sup> examined fish and crayfish in rivers downstream of a waste water treatment plant. The local water and sediment contained significant levels of deca-BDE and they detected a number of PBDE congeners in the fish and crayfish, including three hepta- (BDE-179, -184, -188), and two octa-congeners (BDE-201 and -202) that were not present in the commercial deca-BDE mixture.

Sparrowhawks, buzzards, owls and kestrels in China were investigated for uptake of deca-BDE (BDE-209) from the environment (Da Chen *et al.* (2007)).<sup>22</sup> In addition to BDE-209, the birds' tissues were also found to contain a nona-BDE (BDE-207) and other congeners that may result from debromination of deca-BDE through physical or biological reactions or by direct uptake of such species that have been produced in the environment from BDE-209.

The egg yolk and plasma of male and female glaucous gulls (*Larus hyperboreus*) from the Norwegian Arctic were found to contain a number of brominated flame retardant substances, including three nona-BDEs (BDE-206, -207 and -208) that appear to be the products of reductive debromination of deca-BDE (BDE-209) (Verreault *et al.* (2007)).<sup>23</sup> Like the Chinese birds mentioned above, the source of the reductively debrominated compounds is unknown.

The marine food web in Bohai Bay, North China, was studied by Yi Wan *et al.* (2008)<sup>24</sup>, who reported that BDE-47 was the predominant PBDE in most samples and that concentrations of this substance were biomagnified in the food web. Changes in relative concentrations with trophic level (zooplankton to gulls) led to the conclusion that BDE-99 was biotransformed into BDE-47.

The absorption, distribution, metabolism, and excretion of decaBDE were studied in rats by Morck *et al.* (2003)<sup>25</sup> after a single oral dose of decaBDE. Metabolites with five to seven bromine atoms were formed possessing a hydroxy and methoxy group in one of the rings (guaiacol structure). In addition, traces of nonaBDEs were formed along with monohydroxylated metabolites.

Debromination of decaBDE was studied in male Sprague – Dawley rats by Huwe *et al.* (2007)<sup>26</sup> following dietary exposure using multiple low doses of decaBDE. BDE-209, three nonaBDEs, and four octaBDEs accumulated in the rats and were distributed proportionately throughout the body. Only 5% of the parent decaBDE was present in the rats after 21 days.

The disposition of decaBDE and its metabolites was studied in pregnant Wistar rats by Riu *et al.* (2008)<sup>27</sup> after force feeding with pure decaBDE over 96 hours at a late stage of gestation. Transformation products were observed in tissues and in fetuses including three nonaBDEs and one octaBDE. The authors note that decaBDE and very likely most of its metabolites can cross the placental barrier in rats.

Thuresson *et al.* (2005)<sup>28</sup> found that workers exposed occupationally to c-DecaBDE contain heptaBDE and octaBDE congeners that are not present in the commercial c-DecaBDE mixture or in reference groups. A follow up study found that reduced exposure decreased the decaBDE concentrations but increased the heptaBDE and octaBDE concentrations suggesting that debromination was occurring in humans (Thuresson *et al.* (2006)).<sup>29</sup>

There is a sizeable body of data on the properties of c-DecaBDE that are relevant to its debromination to form components of c-OctaBDE. C-DecaBDE is found in fish, birds, grizzly bears, and other animals at high concentrations, demonstrating that deca-BDE can be absorbed by biological systems.<sup>30 31 32</sup> Deca-BDE can be absorbed by dietary intake in carp, lake trout and rats<sup>33 34 35 36</sup> Given that animal uptake rates are usually in the range of 1 – 3 % of a given dose of decaBDE<sup>37</sup>, high concentrations in terrestrial animals<sup>38 39</sup> suggest that decaBDE can bioaccumulate<sup>40</sup>. Levels of PBDEs in the human population have been rising steadily for the past thirty years and concentrations are doubling approximately every five years.<sup>41</sup> DecaBDE levels are rising along with the levels of other PBDEs in the general population.<sup>42</sup> Finally, DecaBDE has been measured in human blood and breast milk<sup>43 44</sup> and at high levels in electronics recycling workers.<sup>45</sup>

## Summary information relevant to the risk management evaluation

### 3.1 Possible control measures

Deleted: Management options

There are in principle several control measures that could be implemented to reduce the use of c-OctaBDE and/or reduce the environmental impacts associated with the use of the substance, but many of these lie outside the scope of the Stockholm Convention. These include voluntary commitments by industry; eco-labelling schemes; economic instruments; and a deposit refund system.

A ban/restriction on the production and use of c-OctaBDE **and the** components of the commercial mixture would be an effective measure if properly enforced. Some countries have already taken such actions. Standards aiming at reducing the concentrations of bromodiphenyl ethers in products would be very effective (RPA, 2001). Standards could be used to ensure environmentally benign waste handling. Risk management would be best achieved by a global ban on production and use of c-OctaBDE, brought about by listing the components of the mixture under the Stockholm Convention. Suitable, more environmentally benign alternatives exist for all uses of c-OctaBDE so a ban could cover all sectors. A ban would eliminate emissions from the manufacturing of c-OctaBDE, and also eliminate release of bromodiphenyl ethers from the production and use of c-OctaBDE in new products. An important consideration is that a simple ban would not affect the emissions from c-OctaBDE in products already in use.

Deleted: or key

**Since components of the c-OctaBDE mixture are also formed in the environment by debromination of decaBDE, a ban/restriction on the production and use of decaBDE would be an effective measure if properly enforced. Some countries and states have already taken such actions. Risk management would be best achieved by listing c-octaBDE in Annex C of the Stockholm Convention. Suitable, more environmentally benign alternatives exist for all uses of c-DecaBDE so a ban could cover all sectors. A ban would eliminate c-octaBDE emissions from the debromination of decaBDE. An important consideration is that a simple**

**ban would not affect the emissions resulting from debromination of decaBDE in products already in use.**

**A ban on the production and use of c-OctaBDE and decaBDE would also affect waste issues. Listing a substance under the Stockholm Convention implies a ban on recycling and reuse of stockpiles and to treat contaminated sites. Article 6 of the Convention requires that wastes and stockpiles are handled in a safe, efficient and environmentally sound manner, so that the content is destroyed or irreversibly transformed. The article also bans disposal operations that lead to recovery, recycling, reclamation, direct use or alternative use of the POPs material.**

Various control measures at the production or waste handling facilities would ensure safe work environments and regulations on waste handling of products etc. These measures could be applied at waste handling facilities. If properly designed and enforced this could be an effective tool to reduce releases from the sources in question.

### **Efficacy and efficiency of possible control measures**

The choice of control measure for the remaining use and production of c-OctaBDE must take into account that most developed countries have phased out production of c-OctaBDE. However, action is still needed for the protection of human health and the environment from emissions and releases of the components of c-OctaBDE. Further risk reduction options should be examined against the following criteria (RPA, 2001):

- *Effectiveness*: the measure must be targeted at the significant hazardous effects and routes of exposure identified by the risk assessment. The measure must be capable of reducing the risks that need to be limited within and over a reasonable period of time.
- *Practicality*: the measure should be implementable, enforceable and as simple as possible to manage. Priority should be given to commonly used measures that could be carried out within the existing infrastructure.
- *Economic impact*: the impact of the measure on producers, processors, users and other parties should be as low as possible **while still maintaining effectiveness**.
- *Monitorability*: monitoring should be possible to allow the success of risk reduction to be assessed.

### **Waste handling**

A ban on production and use of c-OctaBDE would not in itself affect emissions of its components of concern from waste handling, where they can present a technical and legacy problem. However, listing a substance under the Stockholm Convention implies a ban on recycling and reuse of stockpiles of c-OctaBDE itself. Article 6 in the Convention requires that wastes and stockpiles are handled in a safe, efficient and environmentally sound manner, so that the content is destroyed or irreversibly transformed, taking into account international rules, standards and guidelines. The article also bans disposal operations that lead to recovery, recycling, reclamation, direct use or alternative use of POPs material.

A special challenge could be to separate c-OctaBDE -containing articles from those without the substance, since most articles are not labelled telling what they contain. However, there is information about articles that have contained c-OctaBDE in the past and about which articles it is used in today, like electronic articles, textiles and isolation material and casing materials. National

authorities would have to make surveys to get more detailed information about c-OctaBDE content in different articles becoming waste. Technically the challenge would be the separation of bromine-containing and non-bromine-containing plastic components. Technologies on this field are emerging, thus aiding waste management and possible recycling, but they are expensive.

Targets for phase out of the use of existing products containing c-OctaBDE and the collection of these could be considered according to Annex A or B of the Convention. Since there are substantial stocks of products containing c-OctaBDE in use, national authorities could consider some additional measures to limit releases. These measures could range from establishing collection points where people can deliver their used products to more actively promoting and encouraging people to deliver their waste products. A deposit-refund system does not seem appropriate since sales of new products containing c-OctaBDE would no longer be allowed and their presence has become a legacy problem. However, paying people a fee to deliver their products would be an option, although a source of funding for such an operation is not obvious.

A special challenge would be to ensure proper handling of c-OctaBDE-containing waste material/articles in developing countries. Since these countries have limited experience in handling this kind of waste, they would need practical help and information as well as financial help to ensure environmentally benign handling of this waste. The assistance could include how to dismantle c-OctaBDE-containing articles, treat the various parts and the methods of environmentally sound treatment of the final c-OctaBDE. If listed under the Stockholm Convention, guidelines on sound waste treatment of c-OctaBDE and articles containing c-OctaBDE will be developed under the Basel Convention (Article 6 para 2 of the Stockholm Convention).

### 3.2 Substitution of c-OctaBDE

The phase out of c-OctaBDE is already advanced: production has stopped in the EU, USA and Canada. Voluntary phase out by industry is underway in Japan. In the light of the ban and phase out of c-OctaBDE in 2004 in the European Union and an already increasing use of alternatives, the availability of practicable and economically viable substitutes has already been demonstrated in practice.

Environmental Health Criteria 192 on Flame Retardants (WHO, 1997) provides a general review of all flame retardants and their effects to the human health and the environment. **Alternatives to C-OctaBDE include substitute chemicals and alternative techniques including non-chemical alternatives such as design changes. These are described in several governmental reports.**<sup>42 43 44 45 46</sup> **The German Environmental Protection Agency has published a guidance document for the application of environmentally safe substances which focuses on substitution of PBDEs. The study focuses on substitution of c-decaBDE but it is stated that the results can be used for the substitution of other additive type flame retardants (UBA, 2003b).**

**Comment [J18]:** To reduce the length of the RME, a separate INF document could be developed as done for pentaBDE where much of the valuable information about alternatives was preserved and available for Parties

<sup>42</sup> Environment Canada, Regulatory Impact Analysis Statement for proposed Polybrominated Diphenyl Ether Regulations, 2006 <http://www.ec.gc.ca/CEPARegistry/regulations/detailReg.cfm?intReg=108>

<sup>43</sup> Leisewitz, A., H. Kruse and E. Schramm. German Federal Ministry of the Environment, Nature Conservation and Nuclear Safety, Substituting Environmentally Relevant Flame Retardants: Assessment Fundamentals. Research report 204 08 642 or 207 44 542, 2000

<sup>44</sup> Washington State, USA. Polybrominated Diphenyl Ether (PBDE) Chemical Action Plan: Draft Final Plan, December 1, 2005

<sup>45</sup> Risk and Policy Analysts Limited for Department for Environment, Food and Rural Affairs, UK. Risk reduction strategy and analysis of advantages and drawbacks for octabromodiphenyl ether. 24 June 2002

<sup>46</sup> Danish Environmental Protection Agency, Brominated flame retardants: Substance flow analysis and assessment of alternatives, June 1999

Among the countries that responded to the UNECE survey 2007 Belgium, Czech Republic, Cyprus, Germany, the UK, Switzerland and the USA indicated to have no information on possible substitutes of c-OctaBDE (Italy did not respond to the relevant question). France refers to the RPA Risk reduction strategy (RPA, 2002) and analysis of advantages and drawbacks for c-OctaBDE and states that, instead of looking for a chemical substitution, it may be worth investigating possibilities of eco-design that lower risks of ignition.

### **Design changes to address c-OctaBDE**

**Design changes can eliminate the need for flame retardants by using alternative materials or designs that eliminate the need for chemical flame retardants. These include shielding the plastic outer casing of components with metal or making the entire case of metal.<sup>47 48</sup> Whilst there is inadequate data to estimate the likely costs of such techniques, it is considered that they are likely to be more expensive than using c-OctaBDE in most cases, at least in the short-term.**

**According to the RPA report (RPA, 2002), there are also other options for replacing c-OctaBDE, without utilising a substitute flame retardant. These include re-design of the electrical or electronic products or use of polymers with lower rates of combustion. Other options described in the RPA report<sup>49</sup> include maintaining certain distances between high voltage parts and the outer casings and using polymers with low rates of combustion such as amino-, phenol-, fluoro-, and silicone-based polymers.**

**In some cases design changes can occur by utilizing plastics or blends of polymers that contain different substances for flame retardation.<sup>50</sup> The RPA report mentions use of polycarbonate / ABS blends (PC/ABS) and polypropylene / polystyrene (PPE/PS) blends.**

**Two flame retardants used in the polymer blends are triphenyl phosphate (TPP) and bis (diphenylphosphate) (RDP). US EPA reports moderate systemic toxicity and high acute and chronic ecotoxicity of TPP as two characteristics of concern.<sup>51</sup> The US Occupational Safety and Health Administration (OSHA) reports inhibition of cholinesterase as a health effect of triphenyl phosphate exposure.<sup>52</sup> Bioconcentration factors for TPP in several fish species vary from 6 – 18,900.<sup>53</sup> In addition, triphenyl phosphate is considered environmentally hazardous in Germany due to its toxicity to aquatic organisms.<sup>54</sup> RDP also appears to be harmful to**

**Deleted:** According to BSEF tetrabromobisphenol A (TBBP-A; minor use) can be used as substitute for c-OctaBDE as flame retardant in polymer pellets. Another possibility is the use of alternative polymers that are less inflammable (eg. PVC, PC/ABS) or the use of other flame retardants (UNECE survey 2007, BSEF).¶

**Deleted:** The report "Risk Reduction Strategy and Analysis of Advantages and Drawbacks for Octabromodiphenyl Ether" (RPA, 2002) preceding the EU level control measures contains an analysis on the suitability of various alternatives to c-OctaBDE in terms of technical performance, health and environmental risks and cost implications. Potential alternatives identified include tetrabromobisphenol-A, 1,2-bis(pentabromophenoxy) ethane, 1,2-bis(tribromophenoxy) ethane, triphenyl phosphate, resorcinol bis (diphenylphosphate) and brominated polystyrene. A summary of potential substitution options compared to OctaBDE is presented in Table 6.¶

**Formatted:** Font: Bold

**Deleted:** ¶

**Formatted:** Space Before: 0 pt, After: 0 pt

<sup>47</sup> Danish Environmental Protection Agency, Brominated flame retardants: Substance flow analysis and assessment of alternatives, June 1999

<sup>48</sup> Risk and Policy Analysts Limited for Department for Environment, Food and Rural Affairs, UK. Risk reduction strategy and analysis of advantages and drawbacks for octabromodiphenyl ether. 24 June 2002

<sup>49</sup> Risk and Policy Analysts Limited for Department for Environment, Food and Rural Affairs, UK. Risk reduction strategy and analysis of advantages and drawbacks for octabromodiphenyl ether. 24 June 2002

<sup>50</sup> Risk and Policy Analysts Limited for Department for Environment, Food and Rural Affairs, UK. Risk reduction strategy and analysis of advantages and drawbacks for octabromodiphenyl ether. 24 June 2002

<sup>51</sup> USEPA, Environmental Profiles of Chemical Flame-Retardant Alternatives Polyurethane Foam <http://www.epa.gov/dfepubs/index.htm#ffr>

<sup>52</sup> US Occupational Safety and Health Administration, Chemical Sampling Information, 19 January 1999 [http://www.osha.gov/dts/chemicalsampling/data/CH\\_274400.html](http://www.osha.gov/dts/chemicalsampling/data/CH_274400.html)

<sup>53</sup> Danish Environmental Protection Agency, Brominated flame retardants: Substance flow analysis and assessment of alternatives, June 1999

<sup>54</sup> Leisewitz A, Kruse H, Schramm E, German Federal Ministry of the Environment, Nature Conservation, and Nuclear Safety, Substituting Environmentally relevant flame retardants: Assessment Fundamentals, Research Report 204 08 642 or 207 44 542, 2000

aquatic organizations and estimates on losses from products to the environment is lacking.<sup>55</sup> While TPP and RDP have hazardous properties that must be addressed across their lifecycle, neither is persistent and RDP does not appear to be bioaccumulative.

#### Chemical substitutes for c-OctaBDE in ABS plastic

The report “Risk Reduction Strategy and Analysis of Advantages and Drawbacks for Octabromodiphenyl Ether” (RPA, 2002) preceding the EU level control measures contains an analysis on the suitability of various alternatives to c-OctaBDE in terms of technical performance, health and environmental risks and cost implications. Potential alternatives identified include tetrabromobisphenol-A, 1,2-bis(pentabromophenoxy) ethane, 1,2-bis(tribromophenoxy) ethane, triphenyl phosphate, resorcinol bis (diphenylphosphate) and brominated polystyrene. A summary of potential chemical substitution options compared to OctaBDE is presented in Table 6.

In ABS, TBBPA and brominated epoxy oligomers are used as additive flame retardants meaning that they are not bound to the polymer and therefore have a greater tendency to be released to the environment. TBBPA is a cytotoxicant, immunotoxicant, and thyroid hormone agonist with the potential to disrupt estrogen signaling.<sup>56</sup> TBBPA is classified as very toxic to aquatic organisms and is on the OSPAR Commission’s List of Chemicals for Priority Action due to its persistence and toxicity.<sup>57 58</sup> To avoid their use in ABS applications, poly (phenylene oxide) / high impact polystyrene (PPO / HIPS) blends flame retarded with resorcinol diphosphate (RDP) have been proposed.<sup>59</sup>

Bisphosphate and its derivatives include RDP and are used in “Blue Angel” printers and PCs with PC / ABS casings.<sup>60</sup> The US EPA DfE report lists triaryl phosphate and an isopropylated derivative as having moderate bioaccumulation properties based on structure activity relationships.<sup>61</sup> Bis (tribromophenoxy) ethane is poorly characterized. Studies by its manufacturer indicate low toxicity, but the substance tends to persist and bioaccumulate.<sup>62</sup>

#### Chemical substitutes for c-OctaBDE in synthetic textiles

<sup>55</sup> Risk and Policy Analysts Limited for Department for Environment, Food and Rural Affairs, UK. Risk reduction strategy and analysis of advantages and drawbacks for octabromodiphenyl ether. 24 June 2002

<sup>56</sup> Birnbaum LS, Staskal DF. U.S. Environmental Protection Agency, Office of Research and Development, National Health and Environmental Effects Research Laboratory, Experimental Toxicology Division, Research Triangle Park, North Carolina, USA; and University of North Carolina, Curriculum in Toxicology, Chapel Hill, North Carolina, USA, Brominated flame retardants: Cause for concern? Environ Health Perspect 112: 9 – 17, 2004  
<http://www.ehponline.org/members/2003/6559/6559.html>

<sup>57</sup> Risk and Policy Analysts Limited for Department for Environment, Food and Rural Affairs, UK. Risk reduction strategy and analysis of advantages and drawbacks for octabromodiphenyl ether. 24 June 2002

<sup>58</sup> OSPAR Convention for the Protection of the Marine Environment of the Northeast Atlantic, Tetrabromobisphenol-A OSPAR Commission Update, 2005

[http://www.ospar.org/documents/dbase/publications/p00202\\_BD%20on%20TBBPA.pdf](http://www.ospar.org/documents/dbase/publications/p00202_BD%20on%20TBBPA.pdf)

<sup>59</sup> Morose G. An overview of alternatives to tetrabromobisphenol A (TBBPA) and hexabromocyclododecane (HBCD), Lowell Center for Sustainable Production, University of Massachusetts – Lowell, March 2006  
<http://sustainableproduction.org/downloads/AlternativestoTBBPAandHBCD.pdf>

<sup>60</sup> Leisewitz A, Kruse H, Schramm E, German Federal Ministry of the Environment, Nature Conservation, and Nuclear Safety, Substituting Environmentally relevant flame retardants: Assessment Fundamentals, Research Report 204 08 642 or 207 44 542, 2000

<sup>61</sup> USEPA, Environmental Profiles of Chemical Flame-Retardant Alternatives Polyurethane Foam <http://www.epa.gov/dfe/pubs/index.htm#ffi>

<sup>62</sup> Washington State, USA. Polybrominated Diphenyl Ether (PBDE) Chemical Action Plan: Draft Final Plan, December 1, 2005

Formatted: Font: Bold

Formatted: Caption, Space Before: 0 pt, After: 0 pt

Formatted: Font: Bold

Formatted: Font: Bold

Reactive type flame retardants are usually used in thermosetting material (e.g. polyester resins, epoxy resins, polyurethanes). Chemical substitutes for c-OctaBDE in textiles include reactive phosphorous constituents and hexabromocyclododecane. Specific reactive phosphorous constituents were not identified in the Danish report though polyglycol esters of methyl phosphonic acid (CAS 676-97-1) have been used for flame retardants in polyurethane foam (e.g. CAS 294675-51-7).<sup>63</sup> Methyl phosphonic acid has attracted the attention of those working on chemical weapons since it is a degradation product of VX, sarin, and soman.<sup>64</sup> Researchers at the Oak Ridge National Laboratory in the US describe methyl phosphonic acid as one of degradation products of chemical weapons with “significant persistence.”<sup>65</sup> However, methyl phosphonic acid does not appear to be bioaccumulative.<sup>66</sup> Other types of toxicity information are minimal but note that the substance reacts violently with water.<sup>67</sup> The phosphonic acid family also includes amino-methyl phosphonic acid, a degradation product of the herbicide, glyphosate (also known as [carboxymethylamino] methyl phosphonic acid.)

Hexabromocyclododecane (HBCD) is used as an additive flame retardant indicating that it is not bound to the polymer and therefore has a greater tendency to be released to the environment. HBCD is bioaccumulative, persistent, and causes neurobehavioral alterations in vitro.<sup>68</sup>

#### **Chemical substitutes for c-OctaBDE in thermoplastic elastomers**

Usually additive type flame retardants are used in thermoplastic material (e.g. Polypropylen, Polyethylen, Ethylen-Vinylacetate, PVC).

Chemical substitutes for c-OctaBDE in thermoplastic elastomers include bis (tribromophenoxy) ethane and tribromophenyl allyl ether.<sup>69</sup> Bis (tribromophenoxy) ethane is discussed above under alternatives for c-OctaBDE in ABS plastic. Very little information was available for tribromophenyl allyl ether, though it is on a list of flame retardants considered “deferred” for testing by the interagency testing committee of US EPA.<sup>70</sup>

#### **Chemical substitutes for c-OctaBDE in polyolefins**

<sup>63</sup> Danish Environmental Protection Agency, Brominated flame retardants: Substance flow analysis and assessment of alternatives, June 1999

<sup>64</sup> OPCW Declarations Branch, Some Scheduled Chemicals, 2006  
<http://www.opcw.org/docs/publications/some%20scheduled%20chemicals.pdf>

<sup>65</sup> Munro NB, Talmage SS, Griffin GD, Waters LC, Watson AP, King JF, Hauschild V. Life Sciences Division, Oak Ridge National Laboratory, Oak Ridge, TN 37830, USA. The sources, fate, and toxicity of chemical warfare agent degradation products. Environ. Health Perspect. 107 (12): 933-974. 1999

<sup>66</sup> Munro NB, Talmage SS, Griffin GD, Waters LC, Watson AP, King JF, Hauschild V. The sources, fate, and toxicity of chemical warfare agent degradation. Environ Health Perspect 107:933-974, 1999  
<http://www.ehponline.org/docs/1999/107p933-974munro/munro.pdf>

<sup>67</sup> US EPA Chemical Profile: methyl phosphonic dichloride. Extremely hazardous substances, section 302 of EPCRA, Chemical Emergency Preparedness and Prevention, 1985  
<http://yosemite.epa.gov/oswer/ceppoehs.nsf/Profiles/676-97-1?OpenDocument>

<sup>68</sup> Birnbaum LS, Staskal DF. U.S. Environmental Protection Agency, Office of Research and Development, National Health and Environmental Effects Research Laboratory, Experimental Toxicology Division, Research Triangle Park, North Carolina, USA; and University of North Carolina, Curriculum in Toxicology, Chapel Hill, North Carolina, USA. Brominated flame retardants: Cause for concern? Environ Health Perspect 112: 9 – 17, 2004

<sup>69</sup> Danish Environmental Protection Agency, Brominated flame retardants: Substance flow analysis and assessment of alternatives, June 1999

<sup>70</sup> IPCS Environmental Health Criteria 192. Flame retardants: A general introduction 1997  
<http://www.inchem.org/documents/ehc/ehc/ehc192.htm>

Formatted: Font: Bold

Formatted: Normal, Don't adjust space between Latin and Asian text, Don't adjust space between Asian text and numbers

Formatted: Font: Bold

Chemical substitutes for c-OctaBDE in polyolefins include polypropylene-dibromostyrene, dibromostyrene, and tetrabromobisphenol A (TBBPA).<sup>71</sup> Tetrabromobisphenol A is described above in chemical substitute alternatives for c-OctaBDE in ABS plastic. Few data are available for dibromostyrene and polypropylene-dibromostyrene. For dibromostyrene, an EU assessment found insufficient information on toxicity, no bioaccumulation based on a low BCF value, and overall persistence of 49 days based on modeling.<sup>72</sup>

Formatted: Font: Bold

### Assessing c-OctaBDE alternatives

The RPA report summarizes the alternatives for c-OctaBDE by noting the lack of comprehensive data available for the chemical alternatives and pointing out the viability of non-chemical alternatives such as shielding the plastic outer casing of components with metal or making the entire case of metal, maintaining certain distances between high voltage parts and the outer casings, and using polymers with low rates of combustion such as amino-, phenol-, fluoro-, and silicone-based polymers.<sup>73 74</sup>

Generally it is considered that a substitution by additive type flame retardants that are PBT (i.e. Persistent, Bioaccumulative and Toxic) such as PBDEs, SCCPs (short chain chlorinated paraffin), MCCPs (medium chain chlorinated paraffin) or additive TBBP-A is related to a higher risk of release to the environment during use and disposal of products – irrelevant whether they contain halogens, nitrogen or phosphorus – compared to reactive type flame retardants. Halogenated flame retardants are in addition related to the risk to generate non-desired reaction products in the case of fires (UBA, 2003b).

The use of halogenated flame retardants in the EU is significantly decreasing (with the exception of chlorinated phosphoric esters). Mineral type flame retardants such as Aluminum-tri-hydroxide (ATH) or Magnesium-hydroxide or Nitrogen containing flame retardants (e.g. melamin derivatives) show significant increases. An important driving force for these market adjustments is the consideration of environmental risks (UBA, 2003b).

Two chemical substitutes are both persistent and bioaccumulative: bis (tribromophenoxy) ethane and hexabromocyclododecane. In addition, dibromostyrene was somewhat persistent and not bioaccumulative based on a low BCF value.

The remaining chemical alternatives, while not both persistent and bioaccumulative, still have characteristics that raise some concerns about human health and the environment. The core substance of the reactive phosphorous constituent, methyl phosphonic acid, is persistent. Triphenyl phosphate is bioaccumulative since bioconcentration factors in several fish species vary from 6 – 18,900.<sup>75</sup> Resorcinol bis (diphenylphosphate) is neither persistent nor

<sup>71</sup> Danish Environmental Protection Agency, Brominated flame retardants: Substance flow analysis and assessment of alternatives, June 1999

<sup>72</sup> Pakalin S, Cole T, Steinkellner, Nicolas R, Tissier C, Munn S, Eisenreich S. Review on production processes of decabromodiphenyl ether (decaBDE) used in polymeric applications in electrical and electronic equipment, and assessment of the availability of potential alternatives to decaBDE. European Commission, Directorate General Joint Research Center, European Chemicals Bureau, January 2007  
[http://ecb.jrc.it/documents/Existing-Chemicals/Review\\_on\\_production\\_process\\_of\\_decaBDE.pdf](http://ecb.jrc.it/documents/Existing-Chemicals/Review_on_production_process_of_decaBDE.pdf)

<sup>73</sup> Danish Environmental Protection Agency, Brominated flame retardants: Substance flow analysis and assessment of alternatives, June 1999

<sup>74</sup> Risk and Policy Analysts Limited for Department for Environment, Food and Rural Affairs, UK. Risk reduction strategy and analysis of advantages and drawbacks for octabromodiphenyl ether. 24 June 2002

<sup>75</sup> Danish Environmental Protection Agency, Brominated flame retardants: Substance flow analysis and assessment of alternatives, June 1999

bioaccumulative, however its triphenyl phosphate degradation product has moderate concern for bioaccumulation and it is harmful to aquatic organisms.<sup>76 77 78</sup> Information is sparse for three substitutes: triaryl phosphates butylated, bisphosphate, and tribromophenyl allyl ether.

Halogen free flame retardants are suitable substitutes in many relevant cases. In electric and electronic equipment an efficient flame retardancy of used plastics is important. Approximately 25 % of all plastic components in this sector are flame retarded. The main share thereof is thermoplastic housings, followed by thermosetting printed circuit boards and electronic small parts. For thermoplastic housings suitable and efficient substitutes are available. In injection moulding for thermoplastic housings the fluidness is a critical parameter. Therefore mineral type flame retardants are not appropriate substitutes. Suitable alternatives that have to be evaluated in each single case are (according to UBA, 2003b) for example:

- halogen free systems on phosphorus-organic basis (organic triaryl- and bisphosphates such as phenylcresylphosphate mixtures, triphenylphosphate, resorcinolbis(diphenyl)phosphate or bisphenol-A-diphenylphosphate for PC/ABS and high-impact HIPS housings).
- brominated systems with low dioxin/furan formation potential, in particular with respect to recycling/recovery processes (e.g. 1,2-bis(pentabromophenyl)ethane or ethylenbis(tetra-bromophthalate)).

Formatted: Bullets and Numbering

It has to be noted that the halogen free systems based on organophosphorus compounds cannot be generally considered to be the environmentally preferable substitute. However, the ecologic advantages outweigh the disadvantages at least in comparison with decaBDE or additive TBBP-A if

- substances that have been sufficiently tested for toxicological properties and have proven degradability and low volatility are used as additive type flame retardant in these systems or
- organophosphates that have been sufficiently tested for toxicological properties are used as reactive type flame retardant.

Formatted: Bullets and Numbering

In the guidance document the technical practicality of substitution is demonstrated by means of several examples (UBA, 2003b).

UBA 2003a contains a comparison of 9 typical flame retardants in plastic materials and considerations on possible adverse effects: decaBDE, TBBP-A (additive), hexabromocyclodecane, trichloropropylphosphate, antimony trioxide, aluminum trihydroxide, ammonium polyphosphate, resorcinol bis(diphenyl)phosphate and zinc borate. The comparison takes health (mutagenicity, genotoxic carcinogenicity, reprotoxicity, carcinogenicity, and allergic effects) and environmental (persistence, bioaccumulation and

<sup>76</sup> Washington State, USA. Polybrominated Diphenyl Ether (PBDE) Chemical Action Plan: Draft Final Plan, December 1, 2005

<sup>77</sup> Rossi M, Heine L. Clean Production Action, Green Blue, The Green Screen for Safer Chemicals – Version 1.0: Evaluating environmentally preferable flame retardants for TV enclosures, 2007 [http://cleanproduction.org/Green\\_Greenscreen.php](http://cleanproduction.org/Green_Greenscreen.php)

<sup>78</sup> Risk and Policy Analysts Limited for Department for Environment, Food and Rural Affairs, UK. Risk reduction strategy and analysis of advantages and drawbacks for octabromodiphenyl ether. 24 June 2002

aquatic toxicity) aspects into consideration. There is no unambiguous result that enables to determine the most appropriate flame retardant. Ammonium polyphosphate has neither CMR (Carcinogenic, Mutagenic, and Reprotoxic) nor PBT (Persistency, Bioaccumulation, Toxicity) properties but has restricted practicability due to technical reasons. This underlines the need that the evaluation has to be done on a case by case basis. However, CMR and PBT substances should generally not be used.

Identifying alternatives for POPs provokes a deeper question about methods to evaluate and compare the hazards of various substances.

One screening guide focuses on evaluating environmentally preferable flame retardants for TV enclosures by developing and using a “Green Screen”.<sup>79</sup> The criteria used by the Green Screen include: hazard endpoints with categories of high, medium, and low; criteria for determining each level of chemical concern; and consideration of degradation products and metabolites. The Screen places a substance into one of four categories: Avoid – very high concern, Use – but search for safer substitutes, Use – but still opportunity for improvement, and Prefer – green chemical. According to Green Screen criteria in examining alternatives to c-DecaBDE, only resorcinol bis (diphenylphosphate) passed the first benchmark to land in benchmark 2: Use – but search for safer substitutes, making it the preferred chemical substitute.

For an overarching approach to the topic of alternatives assessment, the Lowell Center for Sustainable Production has developed an Alternatives Assessment Framework with the goal of, “Creating an open source framework for the relatively quick assessment of safer and more socially just alternatives to chemicals, materials, and products of concern.”<sup>80</sup> The Framework discusses goals, guiding principles, decision making rules, comparative and design assessment, and types of evaluation. Since the Framework is designed to be an open source tool, the Lowell Center encourages companies, NGOs, and governments to use, adapt, and expand on it.

Based upon this analysis, there are alternatives to c-OctaBDE available for which existing data do not indicate an equivalent or higher level of risk to health or the environment. This is especially true for reactive type flame retardants that will have significantly lower emissions during the service life of products. However, for all of the potential substitutes identified, the existing data on toxicological and ecotoxicological effects are fewer than for c-OctaBDE. The RPA report (RPA, 2002) pointed out that, given that none of these substances had yet undergone a risk assessment as rigorous as those carried out under the European Union Risk Assessment, it was inevitably not possible to compare the risks on a like-for-like basis. The results of the further testing and assessment that is ongoing for some of the potential substitutes should help to resolve the differences in data availability to a degree.

---

<sup>79</sup> Rossi M, Heine L. Clean Production Action, Green Blue, The Green Screen for Safer Chemicals – Version 1.0: Evaluating environmentally preferable flame retardants for TV enclosures, 2007 <http://cleanproduction.org/Green.GreenScreen.php>

<sup>80</sup> Rossi M, Tickner J, Geiser K. Alternatives Assessment Framework, Lowell Center for Sustainable Production, Version 1.0, July 2006 [http://www.chemicalspolicy.org/downloads/FinalAltsAssess06\\_000.pdf](http://www.chemicalspolicy.org/downloads/FinalAltsAssess06_000.pdf)

Table 6: Summary of Potential Substitution Options Compared to OctaBDE (RPA, 2002).

Substance	Potential Health Risks a)	Potential Environmental Risks a)	Cost and Other Considerations
Tetrabromobisphenol-A b)	No evidence of equal or greater risks	Data indicate may be classified as 'very toxic to aquatic organisms, may cause long term adverse effects in the aquatic environment' c)	Less expensive (~50%) but greater flame retardant loading required. ESR risk assessment ongoing and concerns expressed about substance in some member states
1,2-bis (pentabromophenoxy) ethane b)	No evidence of equal or greater risks	PBT properties appear of less concern than octa. However, fewer data and BCF values questioned	~ 30% more expensive
1,2-bis (tribromophenoxy) ethane b)	No evidence of equal or greater risks	Very limited data	Greater flame retardant loading probably required; expected to be comparable in price
Triphenyl phosphate	No evidence of equal or greater risks	High toxicity and relatively high potential for bioaccumulation but is readily biodegradable	Less expensive but polymer/flame retardant system expected to be more expensive overall. Poorer plastic recyclability
Resorcinol bis (diphenylphosphate)	No evidence of equal or greater risks	Acutely toxic or very toxic but biodegradable	Less expensive but polymer/flame retardant system expected to be more expensive overall. Poorer plastic recyclability
Brominated polystyrene	No evidence of equal or greater risks (but some concerns expressed re: impurities in commercial product)	No data but losses and exposure expected to be lower	Slightly more expensive

Notes:

- a) Note that in most cases, the information available on toxicological and ecotoxicological effects is less than that for octabromodiphenyl ether.
- b) Can be used in ABS as well as other polymers. Other flame retardants listed are not suitable for use in ABS.

- c) Note that in-service losses will be lower where used as reactive flame retardant in non-ABS polymers.

Canada refers to substitution options compared to c-OctaBDE as provided by RPA (RPA, 2002) and states furthermore that alternative techniques to reduce the use of PBDEs are generally known:

- 1) Use of materials that are less prone to fire hazard in electronics equipment (such as aluminium or "super-plastics" with very high oxygen requirements for combustion);
- 2) use of barrier fabrics, wrapping or coatings for foams to replace chemical flame retardants;
- 3) design-for-environment (DFE) techniques for re-use of components containing PBDEs, as an alternative to landfilling or recycling plastic materials containing PBDEs.

The US EPA has recently completed a preliminary assessment of a PentaBDE substitute, Firemaster® 550

### 3.2 bis Substitution of c-DecaBDE

**C-DecaBDE is used as an additive flame retardant often together with antimony trioxide in plastics (~80%) and textiles (~20%) with the predominate uses including TV enclosures made of high impact polystyrene (HIPS), coated wire, electrical parts, mattresses, draperies, commercial upholstered furniture, cars, airplanes, tents, awnings, and other fabric applications.<sup>81</sup> According to the industry, decaBDE is the highest use brominated flame retardant in the Americas and global volume estimates put use at more 56,400 metric tons in 2003 as opposed to negligible use of octaBDE.<sup>82</sup> A number of reports address non-chemical and chemical alternatives for c-DecaBDE in these uses.<sup>83 84 85 86 87 88 89</sup>**

<sup>81</sup> Pure Strategies, Decabromodiphenyl ether: An investigation of non-halogen substitutes in electronic enclosure and textile applications. Lowell Center for Sustainable Production, University of Massachusetts – Lowell, 2005 <http://sustainableproduction.org/downloads/DecaBDESubstitutesFinal4-15-05.pdf>

<sup>82</sup> Minnesota Pollution Control Agency, Decabromodiphenyl ether (Deca-BDE), A report to the Minnesota legislature, January 15, 2008 <http://www.pca.state.mn.us/publications/reports/lrp-ei-2sy08.pdf>

<sup>83</sup> Lassen C, Havelund S, Leisewitz A, Maxson P. COWI A/S, Denmark; Oko-Recherche BmbH, Germany; Concorde East/West Sprl, Belgium. Deca-BDE and alternatives in electrical and electronic equipment, Danish Ministry of the Environment, 2006 <http://www2.mst.dk/Udgiv/publications/2007/978-87-7052-349-3/pdf/978-87-7052-350-9.pdf>

<sup>84</sup> Pure Strategies, Decabromodiphenyl ether: An investigation of non-halogen substitutes in electronic enclosure and textile applications. Lowell Center for Sustainable Production, University of Massachusetts – Lowell, 2005 <http://sustainableproduction.org/downloads/DecaBDESubstitutesFinal4-15-05.pdf>

<sup>85</sup> Pakalin S, Cole T, Steinkellner J, Nicolas R, Tissier C, Munn S, Eisenreich S. European Chemicals Bureau, Review on production processes of decabromodiphenyl ether (DecaBDE) used in polymeric applications in electrical and electronic equipment, and assessment of the availability of potential alternatives to DecaBDE, European Commission Directorate General Joint Research Center, January 2007 [http://ecb.jrc.it/documents/Existing-Chemicals/Review\\_on\\_production\\_process\\_of\\_decaBDE.pdf](http://ecb.jrc.it/documents/Existing-Chemicals/Review_on_production_process_of_decaBDE.pdf)

<sup>86</sup> Illinois Environmental Protection Agency, Report on alternatives to the flame retardant decaBDE: Evaluation of toxicity, availability, affordability, and fire safety issues. A report to the Governor and State Assembly. March 2007 <http://www.epa.state.il.us/reports/decabde-study/>

<sup>87</sup> Washington State, USA. Polybrominated Diphenyl Ether (PBDE) Chemical Action Plan: Draft Final Plan, December 1, 2005 <http://www.ecy.wa.gov/pubs/0507048.pdf>

<sup>88</sup> Maine Center for Disease Control and Prevention, Brominated flame retardants; Third report to the Maine Legislature, Maine Department of Environmental Protection (USA), 2007 <http://www.maine.gov/dep/rwm/publications/legislative-reports/pdf/finalrptjan07.pdf>

**Deleted:** Based upon this analysis, there are alternatives to c-OctaBDE available for which existing data do not indicate an equivalent or higher level of risk to health or the environment. This is especially true for reactive type flame retardants that will have significantly lower emissions during the service life of products. However, for all of the potential substitutes identified, the existing data on toxicological and ecotoxicological effects are fewer than for c-OctaBDE. The RPA report (RPA, 2002) pointed out that, given that none of these substances had yet undergone a risk assessment as rigorous as those carried out under the European Union Risk Assessment, it was inevitably not possible to compare the risks on a like-for-like basis. The results of the further testing and assessment that is ongoing for some of the potential substitutes should help to resolve the differences in data availability to a degree.¶

According to the RPA report (RPA, 2002), there are also other options for replacing c-OctaBDE, without utilising a substitute flame retardant. These include re-design of the electrical or electronic products or use of polymers with lower rates of combustion. Whilst there is inadequate data to estimate the likely costs of such techniques, it is considered that they are likely to be more expensive than using c-OctaBDE in most cases, at least in the short-term.

**Comment [J19]:** These options could be covered in a systematic way in the text without explicitly referring to a specific country... Propose deletion.

**Comment [J20]:** This seems irrelevant considering the different uses of pentaBDE and octaBDE. Propose to delete

**Deleted:** (main component triphenyl phosphate), and concluded that this alternative chemical is not persistent, bioaccumulative or toxic to aquatic organisms. It is available in the Americas and Asia Pacific regions only. The substitute also provides the important fire safety performance standards necessary for use in consumer products. The Agency will continue to work with Great Lakes and other companies on the development of substitutes, alternatives and additional health and exposure testing on the substitutes. US EPA will also continue its efforts to gain a better scientific understanding of flame retardant chemicals (US EPA, 2003a).¶

### **Design changes to address c-DecaBDE**

A general substitution for uses in electrical equipment is using a metal sheet to cover plastic in contact with electrical parts.<sup>90</sup> In TV design, manufacturers have been able to achieve UL standards by separating the voltage supply from ignitable plastics though this does not flame retard them from external sources of ignition.<sup>91</sup> Other strategies include reducing operating voltage and removing the power supply from the product (used in printers and phones). Redesign of mattresses includes eliminating flammable foam (implemented by Herman Miller furniture), utilizing inherently fire-resistant fabrics (used in fire fighter apparel), and use of barrier layers with boric acid (used in mattresses, upholstered furniture, and draperies; see below).<sup>92</sup>

### **Chemical substitutes for c-DecaBDE in HIPS**

Non-halogenated alternatives for this application include blends of polycarbonate and ABS (PC / ABS), polycarbonate (PC), blends of HIPS and polyphenylene oxide (HIPS / PPO), and polylactide (PLA).<sup>93</sup>

The PC / ABS blends use a flame retardant and polytetrafluoroethylene (PTFE) indicating that they are not halogen-free. Two common flame retardants are resorcinol bis diphenyl phosphate (RDP) and bisphenol a diphosphate (BPADP). Resorcinol bis (diphenylphosphate) is neither persistent nor bioaccumulative, however its triphenyl phosphate degradation product has moderate concern for bioaccumulation and it is harmful to aquatic organisms.<sup>94</sup><sup>95</sup> <sup>96</sup> BPADP has a high potential for persistence and includes triphenyl phosphate as a degradation product.<sup>97</sup> BPADP also includes Bisphenol A as a contaminant and degradation product which displays endocrine disruption, developmental and reproductive toxicity, and other toxic effects.<sup>98</sup> PC may be compounded similarly.

---

<sup>89</sup> Stuer-Lauridsen F, Cohr KH, Andersen TT, DHI Water & Environment, Health and environmental assessment of alternatives to deca-BDE in electrical and electronic equipment, Danish Ministry of the Environment, No. 1142, 2007

<http://www2.mst.dk/Udgiv/publications/2007/978-87-7052-351-6/pdf/978-87-7052-352-3.pdf>

<sup>90</sup> Lassen C, Havelund S, Leisewitz A, Maxson P. COWI A/S, Denmark; Oko-Recherche BmbH, Germany; Concorde East/West Sprl, Belgium. Deca-BDE and alternatives in electrical and electronic equipment, Danish Ministry of the Environment, 2006

<sup>91</sup> Pure Strategies, Decabromodiphenyl ether: An investigation of non-halogen substitutes in electronic enclosure and textile applications. Lowell Center for Sustainable Production, University of Massachusetts – Lowell, 2005 <http://sustainableproduction.org/downloads/DecaBDESubstitutesFinal4-15-05.pdf>

<sup>92</sup> Pure Strategies, Decabromodiphenyl ether: An investigation of non-halogen substitutes in electronic enclosure and textile applications. Lowell Center for Sustainable Production, University of Massachusetts – Lowell, 2005 <http://sustainableproduction.org/downloads/DecaBDESubstitutesFinal4-15-05.pdf>

<sup>93</sup> Pure Strategies, Decabromodiphenyl ether: An investigation of non-halogen substitutes in electronic enclosure and textile applications. Lowell Center for Sustainable Production, University of Massachusetts – Lowell, 2005 <http://sustainableproduction.org/downloads/DecaBDESubstitutesFinal4-15-05.pdf>

<sup>94</sup> Washington State, USA. Polybrominated Diphenyl Ether (PBDE) Chemical Action Plan: Draft Final Plan, December 1, 2005

<sup>95</sup> Rossi M, Heine L. Clean Production Action, Green Blue, The Green Screen for Safer Chemicals – Version 1.0: Evaluating environmentally preferable flame retardants for TV enclosures, 2007 <http://cleanproduction.org/Green.GreenScreen.php>

<sup>96</sup> Risk and Policy Analysts Limited for Department for Environment, Food and Rural Affairs, UK. Risk reduction strategy and analysis of advantages and drawbacks for octabromodiphenyl ether. 24 June 2002

<sup>97</sup> Rossi M, Heine L. Clean Production Action, Green Blue, The Green Screen for Safer Chemicals – Version 1.0: Evaluating environmentally preferable flame retardants for TV enclosures, 2007 <http://cleanproduction.org/Green.GreenScreen.php>

<sup>98</sup> Rossi M, Heine L. Clean Production Action, Green Blue, The Green Screen for Safer Chemicals –

The PPO in the HIPS / PPO blends provide increased flame retardancy and the blends often utilize resorcinol bis diphenyl phosphate (see paragraph above.) These blends have a higher heat tolerance and mechanical strength than HIPS retarded with c-DecaBDE.<sup>99</sup>

Poly lactide needs modification for product applications due to its low melting point and brittleness. However, NEC has made a PLA resin with metal hydroxide flame retardants and kenaf fibers for improved strength making it as heat resistant, easy to process, and strong as PC.<sup>100</sup> JVC, Sony, and Mitsubishi are actively developing PLA materials with aluminum hydroxide flame retardants. The Danish Alternatives report summarizes the toxicity of aluminum hydroxide as very low except when there are high exposure levels or unusual routes of exposure and estimates that it would be extremely unlikely for its use in consumer products to cause adverse effects.<sup>101</sup> The German Alternatives report describes the use of aluminum trihydroxide as a flame retardant as “unproblematic.”<sup>102</sup>

### Chemical substitutes for c-DecaBDE in polypropylene

Non-brominated flame retardants for use in polypropylene or polypropylene ether coated wire and cable include ammonium polyphosphate, magnesium hydroxide, and melamine phosphate.<sup>103</sup>

Ammonium polyphosphate is often used in combination with aluminum trihydroxide. The substance metabolizes into ammonia and phosphate and is not thought to cause acute toxicity in humans.<sup>104</sup> However, there are no analyses of long-term toxicity, teratogenicity, mutagenicity, or carcinogenicity. Ammonium polyphosphate breaks down rapidly and does not accumulate in the food chain. The German Alternatives report concludes that skin irritation is possible due to the formation of phosphoric acids but that the substance appears to be “unproblematic”.<sup>105</sup>

---

Version1.0: Evaluating environmentally preferable flame retardants for TV enclosures, 2007

<http://cleanproduction.org/Green.GreenScreen.php>

<sup>99</sup> Pure Strategies, Decabromodiphenyl ether: An investigation of non-halogen substitutes in electronic enclosure and textile applications. Lowell Center for Sustainable Production, University of Massachusetts – Lowell, 2005 <http://sustainableproduction.org/downloads/DecaBDESubstitutesFinal4-15-05.pdf>

<sup>100</sup> Pure Strategies, Decabromodiphenyl ether: An investigation of non-halogen substitutes in electronic enclosure and textile applications. Lowell Center for Sustainable Production, University of Massachusetts – Lowell, 2005 <http://sustainableproduction.org/downloads/DecaBDESubstitutesFinal4-15-05.pdf>

<sup>101</sup> Danish Environmental Protection Agency, Brominated flame retardants: Substance flow analysis and assessment of alternatives, June 1999  
[http://www2.mst.dk/common/Udgivramme/Frame.asp?pg=http://www2.mst.dk/udgiv/Publications/1999/87-7909-416-3/html/kap08\\_eng.htm](http://www2.mst.dk/common/Udgivramme/Frame.asp?pg=http://www2.mst.dk/udgiv/Publications/1999/87-7909-416-3/html/kap08_eng.htm)

<sup>102</sup> Leisewitz A, Kruse H, Schramm E, German Federal Ministry of the Environment, Nature Conservation, and Nuclear Safety, Substituting Environmentally relevant flame retardants: Assessment Fundamentals, Research Report 204 08 642 or 207 44 542, 2000

<sup>103</sup> Maine Center for Disease Control and Prevention, Brominated flame retardants; Third report to the Maine Legislature, Maine Department of Environmental Protection (USA), 2007  
<http://www.maine.gov/dep/rwm/publications/legislativereports/pdf/finalrptjan07.pdf>

<sup>104</sup> Leisewitz A, Kruse H, Schramm E, German Federal Ministry of the Environment, Nature Conservation, and Nuclear Safety, Substituting Environmentally relevant flame retardants: Assessment Fundamentals, Research Report 204 08 642 or 207 44 542, 2000

<sup>105</sup> Leisewitz A, Kruse H, Schramm E, German Federal Ministry of the Environment, Nature Conservation, and Nuclear Safety, Substituting Environmentally relevant flame retardants: Assessment Fundamentals, Research Report 204 08 642 or 207 44 542, 2000

**Magnesium hydroxide is commonly ingested as an antacid and forms the active ingredient in milk of magnesia. Surprisingly, there is very little toxicological information on magnesium hydroxide. One possible problem with the its use as a flame retardant is that large amounts of (~50%) are required for effective flame retardancy and this may change the properties of the material.**

**Melamine and its derivatives display several toxic effects. These include changed electrolyte compositions of urine, teratogenic effects in fertilized rainbow trout eggs, and reproductive effects in snails and houseflies.<sup>106</sup> In addition, melamine caused chronic injury to the male rat bladder due to stones formed during exposure which correlated strongly with carcinoma.<sup>107</sup> In a fire, melamine cyanurate will release toxic fumes such as hydrocyanic acid and isocyanate.<sup>108</sup> The Danish report notes that there is no data on emission from products and that melamine appears to have low acute and chronic toxicity. The report concludes that, "...no adverse effects are envisaged from the level of exposure expected from the use of melamine as a flame retardant. At the level of exposure precipitation in the renal tubulus and in the bladder should not be a significant risk."<sup>109</sup> In contrast, the German report describes the lack of data, presence in environmental samples and moderate organ toxicity of melamine and concludes it is a "...problematic substance."<sup>110</sup> Melamine and its derivatives are not both persistent and bioaccumulative.**

#### **Chemical substitutes for c-DecaBDE in polybutylene terephthalate (PBT) and polyamide (PA)**

**Alternatives to brominated flame retardants in this use for electrical parts include magnesium hydroxide, melamine cyanurate, and melamine polyphosphate in polyamide and phosphinic acid in polybutylene terephthalate.<sup>111</sup> See the section above for reviews of magnesium hydroxide and melamine compounds. Phosphinic acid is not well characterized, though the Danish EPA report notes that it is considered to be very persistent.<sup>112</sup>**

#### **Chemical substitutes for c-DecaBDE in mattresses, upholstery, and draperies**

**The choice and feasibility of c-DecaBDE substitutes in textiles can be affected by the fabric which is used since the flame retardancy of various fabrics varies from those that easily burn with a vigorous flame (cotton) to those that burn slowly (wool and silk), to very slowly**

<sup>106</sup> Daugherty ML. Chemical hazard information profile draft report: Melamine, CAS No. 108-78-1, Office of Toxic Substances, US EPA, 1982.

<sup>107</sup> Danish Environmental Protection Agency, Brominated flame retardants: Substance flow analysis and assessment of alternatives, June 1999

<sup>108</sup> Leisewitz A, Kruse H, Schramm E, German Federal Ministry of the Environment, Nature Conservation, and Nuclear Safety, Substituting Environmentally relevant flame retardants: Assessment Fundamentals, Research Report 204 08 642 or 207 44 542, 2000

<sup>109</sup> Danish Environmental Protection Agency, Brominated flame retardants: Substance flow analysis and assessment of alternatives, June 1999

<sup>110</sup> Leisewitz A, Kruse H, Schramm E, German Federal Ministry of the Environment, Nature Conservation, and Nuclear Safety, Substituting Environmentally relevant flame retardants: Assessment Fundamentals, Research Report 204 08 642 or 207 44 542, 2000

<sup>111</sup> Maine Center for Disease Control and Prevention, Brominated flame retardants; Third report to the Maine Legislature, Maine Department of Environmental Protection (USA), 2007  
<http://www.maine.gov/dep/rwm/publications/legislativereports/pdf/finalrptjan07.pdf>

<sup>112</sup> Stuer-Lauridsen F, Cohr KH, Andersen TT, DHI Water & Environment, Health and environmental assessment of alternatives to deca-BDE in electrical and electronic equipment, Danish Ministry of the Environment, No. 1142, 2007

(modacrylic and saran), and even some that do not burn (aramid, novoloid, and melamine.)<sup>113</sup>  
Note that modacrylic synthesis utilizes highly toxic substances such as acrylonitrile and vinyl bromide.<sup>114 115 116 117</sup>

Mattresses can utilize a phosphate-based flame retardant as a coating for mattress fabrics (see above) or fire barriers that place a fire-resistant material in the cushioning or between the exterior cover fabric and the first layer of cushioning.<sup>118</sup> The latter method is commonly used commercially and thought to be applicable to upholstered furniture as well. Draperies can be flame retarded with phosphonate type substances or made using inherently flame-resistant fabrics.<sup>119</sup>

According to industry sources cited in the Pure Strategies report, "...chemical flame retardants are not necessary in 99% of cases for panel and upholstery fabrics to meet the fire codes for residential upholstered furniture."

### Assessing c-DecaBDE alternatives

Given the range of alternative flame retardants and techniques available, a wise course of action would be to examine the toxicity of the substance, its breakdown products, manufacturing processes, and the use of synthetic materials, and give preference to those that pose least risk. As noted in the Danish EPA report, "Criteria for developing functional flame retardants should include non-hazardous synthetic pathway, minimum human and environmental toxicity, minimum release during product use, minimum formation of hazardous substances during incineration or burning, recyclable, degradable, and decompose into a non-hazardous substance."<sup>120</sup>

In general, chemical alternatives that exhibit properties such as persistence and bioaccumulation seem inappropriate as replacements for a POP with these same properties. Two chemical substitutes are persistent: bis (tribromophenoxy) bisphenol a diphosphate (BPADP) and phosphinic acid. Resorcinol bis (diphenylphosphate) is neither persistent nor bioaccumulative, however its triphenyl phosphate degradation product has moderate concern for bioaccumulation and it is harmful to aquatic organisms.<sup>121 122 123</sup> Melamine is not

<sup>113</sup> Pure Strategies, Decabromodiphenyl ether: An investigation of non-halogen substitutes in electronic enclosure and textile applications. Lowell Center for Sustainable Production, University of Massachusetts – Lowell, 2005 <http://sustainableproduction.org/downloads/DecaBDESubstitutesFinal4-15-05.pdf>

<sup>114</sup> <http://www.britannica.com/eb/article-9053135/modacrylic>

<sup>115</sup> National Toxicology Program, Report on carcinogens background document for vinyl bromide.

<http://ntp.niehs.nih.gov/ntp/newhomeroc/roc10/VB.pdf>

<sup>116</sup> <http://www.atsdr.cdc.gov/tfacts125.html>

<sup>117</sup> World Intellectual Property Organization, WO/2005/111289, Fire blocker fiber composition, high loft web structures, and articles made therefrom, undated

<http://www.wipo.int/pctdb/en/wo.jsp?IA=WO2005111289&DISPLAY=DESC>

<sup>118</sup> Pure Strategies, Decabromodiphenyl ether: An investigation of non-halogen substitutes in electronic enclosure and textile applications. Lowell Center for Sustainable Production, University of Massachusetts – Lowell, 2005 <http://sustainableproduction.org/downloads/DecaBDESubstitutesFinal4-15-05.pdf>

<sup>119</sup> Pure Strategies, Decabromodiphenyl ether: An investigation of non-halogen substitutes in electronic enclosure and textile applications. Lowell Center for Sustainable Production, University of Massachusetts – Lowell, 2005 <http://sustainableproduction.org/downloads/DecaBDESubstitutesFinal4-15-05.pdf>

<sup>120</sup> Danish Environmental Protection Agency, Brominated flame retardants: Substance flow analysis and assessment of alternatives, June 1999

<sup>121</sup> Washington State, USA. Polybrominated Diphenyl Ether (PBDE) Chemical Action Plan: Draft Final Plan, December 1, 2005

<sup>122</sup> Rossi M, Heine L. Clean Production Action, Green Blue, The Green Screen for Safer Chemicals – Version 1.0: Evaluating environmentally preferable flame retardants for TV enclosures, 2007

**persistent or bioaccumulative but displays several toxic effects which the German report describes as “problematic”.<sup>124</sup> The metal hydroxides are approved by both the Danish EPA and German reports through they note that more information is needed.<sup>125 126</sup>**

### **3.2 ter Technical feasibility**

**All the alternatives to c-OctaBDE described above are technically feasible and have been used in commercial applications.**

**The EU RPA concluded that, “Based on consultation with industry, it is evident that most companies have already replaced octabromodiphenyl ether in their products with other flame retardants and some companies utilise design measures, rather than flame retardants, for certain types of products. Overall, there does not appear to be any major technical obstacle to replacement of the substance, although some of the flame retardant/polymer combinations considered in this section may have inferior technical performance in certain applications.”<sup>127</sup>**

**Many high profile companies have already implemented alternatives to both c-OctaBDE and c-DecaBDE. For example, Dell (#1 in US PC sales) eliminated all halogenated flame-retardants in all desktop, notebook and server chassis plastic parts in 2004 and has recently expanded these restrictions to include all products designed after June 2006.<sup>128</sup> HP (#2 in US PC sales) has a policy banning use of c-DecaBDE in its products.<sup>129</sup> Toshiba (#4 in US PC sales) does not use c-DecaBDE in their products.<sup>130</sup> Lenovo (#6 in US PC sales) has eliminated PBDEs including c-OctaBDE and c-DecaBDE in all of their products.<sup>131</sup> Samsung (#3 in US TV sales), Sony (#1 in US TV sales), Panasonic (#6 in US TV sales), and Philips (#6 in US TV sales) have eliminated c-DecaBDE from their televisions.<sup>132 133 134</sup> LG Electronics (#8 in US**

---

<http://cleanproduction.org/Green.Greenscreen.php>

<sup>123</sup> Risk and Policy Analysts Limited for Department for Environment, Food and Rural Affairs, UK. Risk reduction strategy and analysis of advantages and drawbacks for octabromodiphenyl ether. 24 June 2002

<sup>124</sup> Leisewitz A, Kruse H, Schramm E, German Federal Ministry of the Environment, Nature Conservation, and Nuclear Safety, Substituting Environmentally relevant flame retardants: Assessment Fundamentals, Research Report 204 08 642 or 207 44 542, 2000

<sup>125</sup> Danish Environmental Protection Agency, Brominated flame retardants: Substance flow analysis and assessment of alternatives, June 1999

<sup>126</sup> Leisewitz A, Kruse H, Schramm E, German Federal Ministry of the Environment, Nature Conservation, and Nuclear Safety, Substituting Environmentally relevant flame retardants: Assessment Fundamentals, Research Report 204 08 642 or 207 44 542, 2000

<sup>127</sup> Risk and Policy Analysts Limited for Department for Environment, Food and Rural Affairs, UK. Risk reduction strategy and analysis of advantages and drawbacks for octabromodiphenyl ether. 24 June 2002

<sup>128</sup> Greiner T, Rossi M, Thorpe B, Kerr B, Healthy Business Strategies for Transforming the Toxic Chemical Economy, Clean Production Action, June 2006, <http://www.cleanproduction.org/library/CPA-HealthyBusiness-1.pdf>

<sup>129</sup> <http://www.hp.com/hpinfo/newsroom/press/2005/051101a.html>

<sup>130</sup> Personal communication from Peter Leone, Manager, Product Safety & Standards Compliance, Toshiba America Information Systems, Inc. to Alexandra McPherson, Clean Production Action, March 30, 2006 as cited in <http://cleanproduction.org/library/Electronics%20BFR%20Fact%20Sheet.pdf>

<sup>131</sup> Pierce, Mike (Lenovo Corporation, Global Environmental Affairs). 2006. Lenovo Engineering Specification 41A7731: Baseline Environmental Requirements for Materials, Parts, and Products for Lenovo Hardware Products. [http://www.pc.ibm.com/www/lenovo/procurement/Guidelines/41A7731\\_J83906N\\_R0\\_WORD\\_SRC.doc](http://www.pc.ibm.com/www/lenovo/procurement/Guidelines/41A7731_J83906N_R0_WORD_SRC.doc)

<sup>132</sup> Personal communication from Michael Moss, Environmental Senior Manager, QA Lab, Samsung Electronics America to Alexandra McPherson, Clean Production Action, November 17, 2006 as cited in <http://cleanproduction.org/library/Electronics%20BFR%20Fact%20Sheet.pdf>

<sup>133</sup> <http://www.sony.net/SonyInfo/procurementinfo/ss00259/>

TV sales) plans to eliminate all c-DecaBDE and all other brominated flame retardants by 2010.<sup>135</sup> A comparison of computer, TV, and game manufacturers on their BFR phase-out timelines and BFR-free products has also been assembled by Greenpeace and is updated every three months.<sup>136</sup>

Additional companies that have phased out c-DecaBDE and other PBDEs in all their products include: IBM, Ericsson, Apple, Matsushita (including Panasonic), Intel, and B&O.<sup>137</sup>

Norway has announced a ban on new products containing decaBDE beginning in April 2008.<sup>138</sup> The pre-existing ban on the use of decaBDE in electronic and electrical products will be extended to textiles, furniture filling and cables leaving the transport sector as the only exemption.

### 3.3 Measures to reduce emissions

The UNECE survey 2007 indicated the lack of information on emission control techniques which are already applied or which may be applied in the near future, such as alternative production processes and technologies, alternative operating practices and/or other pollution prevention techniques to reduce the release of c-OctaBDE to the environment.

No specific studies on c-OctaBDE emission control techniques have been identified.

The main remaining releases of c-OctaBDE occur during the service life and particularly at disposal of products containing c-OctaBDE.

Controlling emissions caused by volatile losses from polymers over their service life is very difficult. The use of reactive type flame retarding compounds could be recommended as one potential measure.

Concerning emission control at disposal, several measures can be taken to reduce possible emissions. They are briefly discussed in this section.

A ban would eliminate emissions from the production, manufacturing and use of c-OctaBDE in new products. It would not affect the emissions from products already in use. Additional regulations could therefore be considered. This would for example be relevant for recycling and dismantling of electronic articles containing c-OctaBDE. Within the EU specific requirements concerning collection, recovery, permitting of treatment installations, treatment standards and separation are already established for plastics containing PBDEs (European Union, 2002).

<sup>134</sup> As cited in <http://www.cleanproduction.org/library/CPA-HealthyBusiness-1.pdf>

<sup>135</sup> As cited in <http://www.cleanproduction.org/library/CPA-HealthyBusiness-1.pdf>

<sup>136</sup> Greenpeace International Guide to Greener Electronics, December 2007

Update: <http://www.greenpeace.org/electronics>

<sup>137</sup> Lassen C, Havelund S, Leisewitz A, Maxson P. COWI A/S, Denmark; Oko-Recherche BmbH, Germany; Concorde East/West Sprl, Belgium. Deca-BDE and alternatives in electrical and electronic equipment, Danish Ministry of the Environment, 200

<http://www2.mst.dk/Udgiv/publications/2007/978-87-7052-349-3/pdf/978-87-7052-350-9.pdf>

<sup>138</sup> END Europe Daily 2465, Norwegians virtually extinguish deca-BDE, 18 January 2008

**Deleted:** The German Environmental Protection Agency has published a guidance document for the application of environmentally safe substances which focuses on substitution of PBDEs. The study focuses on substitution of c-decaBDE but it is stated that the results can be used for the substitution of other additive type flame retardants (UBA, 2003b).¶ It has to be differentiated between flame retardants of the additive type that are physically combined with the material being treated rather than chemically combined, as in reactive flame retardants (such as usually TBPP-A or specific esters of phosphoric acid). Additive type flame retardants may migrate and diffuse out of the treated material to some extent. Usually additive type flame retardants are used in thermoplastic material (e.g. Polypropylen, Polyethylen, Ethylen-Vinylacetate, PVC). They can be applied ex post to the raw polymer. Reactive type flame retardants are usually used in thermosetting material (e.g. polyester resins, epoxy resins, polyurethanes).¶ Generally it is considered that a substitution by additive type flame retardants that are PBT (i.e. Persistent, Bioaccumulative and Toxic) such as PBDEs, SCCPs (short chain chlorinated paraffin), MCCPs (medium chain chlorinated paraffin) or additive TBPP-A is related to a higher risk of release to the environment during use and disposal of products – irrelevant whether they contain halogens, nitrogen or phosphorus – compared to reactive type flame retardants. Halogenated flame retardants are in addition related to the risk to generate non-desired reaction products in the case of fires (UBA, 2003b).¶ The use of halogenated flame retardants in the EU is significantly decreasing (with the exception of chlorinated phosphoric esters). Mineral type flame retardants such as Aluminum-tri-hydroxide (ATH) or Magnesium-hydroxide or Nitrogen containing ... [1]

**Deleted:** Halogen free flame retardants are suitable substitutes in many relevant cases. In electric and electronic equipment an efficient flame retardancy of used plastics is important. Approximately 25 % of all plastic components in this sector are flame retarded. The main share thereof is thermoplastic housings, followed by thermosetting printed circuit boards and electronic small parts. For thermoplastic housings suitable and efficient substitutes are available. In injection moulding for thermoplastic housings the fluidness is a critical parameter. Therefore mineral type flame retardants are not appropriate substitutes. Suitable alternatives that have to be evaluated in each single case are (according to UBA, 2003b) for example:¶ <#>halogen free systems on phosphorus-organic basis (organic triaryl- and bisphosphates such as phenylcresylphosphate mixtures, triphenylphosphate, resorcinolbis(diphenylphosphate) or ... [2]

**Formatted:** Indent: Left: 0", Hanging: 0.43"

Specific measures concerning the handling of waste at disposal and recycling/recovery could be to separate articles containing c-OctaBDE from those without the substance (problematic to identify these articles) and to direct them to controlled disposal (e.g. treatment as hazardous waste) or to set targets for the phase out of the use of existing products containing c-OctaBDE and to implement collection of these products. **There are also concerns over export of electronic waste to developing countries leading to c-OctaBDE releases during recycling operations. In addition, burning or incineration of c-OctaBDE-containing waste could lead to formation and release of brominated dibenzo-*p*-dioxins and furans.**<sup>139</sup>

**Comment [J21]:** XRF guns are portable and can detect Br in articles with an automatic readout to indicate a pass or fail for ROHS or other regulatory standards. US federal agencies use the technology routinely. For example see <http://www.innovxsys.com/en/products/cb/defender>

During the use of c-OctaBDE, there are a number of measures that plastics compounders and processors could take to reduce their environmental emissions of c-OctaBDE. For example, in relation to losses to waste water and air via settling out of dust and subsequent release through washing, companies could alter their practices such that the dust is collected and disposed of as controlled waste. In relation to volatile losses, companies could ensure that all processes are totally closed, preventing losses to the environment, or they could install abatement technology at the site to ensure that any potential emissions are captured (RPA 2002).

**Comment [J22]:** Since an Annex A listing would prohibit use, is this paragraph necessary?

In general measures as identified to reduce environmental emissions at compounders and processors could principally also be applied to disposal, recycling/recovery and dismantling facilities. These should aim to minimise dust and air emissions and to avoid input to waste water. In particular measures could be suggested to reduce releases at disposal by applying BAT/BEP (Best Available Technologies/Best Environmental Performance) at disposal and recycling/dismantling/reuse. A source for possible measures could be the BREF<sup>140</sup> on waste treatment, even if specific measures for recycling/recovery and dismantling have not been identified in the BREF (European Commission, 2006). Possible measures include simple technical and organisational measures and end-of-pipe controls reducing releases to the environment such as

**Comment [J23]:** Perhaps the BREF could be updated specifically for dealing with PBDE wastes in articles.

- considering generic techniques applied to waste storage (e.g. controlled run-off from storage places; using polymer sheeting to cover open solids storage facilities that may generate particulates);
- considering techniques to reduce water use and prevent water contamination (e.g. by vacuuming and dust collection in preference to hosing down);
- minimising dust input to waste water and dust collection and disposal as controlled waste (incineration or landfill);
- applying appropriate waste water treatment;
- using local exhaust ventilation to control dust and volatile emissions;
- shredding in closed systems including dust separation and thermal treatment of exhaust air.

### 3.4 Impacts on society of implementing possible control measures

<sup>139</sup> Leisewitz, A., H. Kruse and E. Schramm. German Federal Ministry of the Environment, Nature Conservation and Nuclear Safety, Substituting Environmentally Relevant Flame Retardants: Assessment Fundamentals. Research report 204 08 642 or 207 44 542, 2000

<sup>140</sup> **BREF = Best available techniques REFerence document**

**Formatted:** English (U.S.)

## Benefits of phasing-out c-OctaBDE

The most obvious benefits to the global society of phasing out c-OctaBDE would be the reduced risk to human health and the environment due to reduced releases to air, water and soil of the components considered to be POPs, as well as releases in workplace settings (UNEP, 2007b). c-OctaBDE is readily incorporated into the food chain and bioaccumulates in the fatty tissues of top predators, including humans. They have been detected levels of concern in several endangered species.

Levels of c-OctaBDE have been found in humans in all regions of the world (UNEP, 2007b). Potential exposure of humans is through food, use of products containing c-OctaBDE. c-OctaBDE transfers from mothers to embryos and breastfed infants. UNEP (UNEP, 2007b), in its assessment, concludes that c-OctaBDE is likely to cause significant adverse effects on human health or the environment, such that global action is warranted. Continued use will entail a potentially large cost.

Fire prevention is important to protect human safety, and to avoid social and economic losses due to fire, but also to prevent spread in the environment of toxic materials released in fires. Using less of the flame retardant substances, or less effective agents, could therefore cause losses if fires become more frequent, but according to European Commission (European Commission, 2005), the available alternatives function as well as c-OctaBDE. Most of the alternatives are in themselves less hazardous to the environment than c-OctaBDE.

An estimate should be made of the reduced cost to the society from reduced damage to ecosystems and to public health, when materials like c-OctaBDE are removed from the market. The value of reduced damage to environment and health is difficult to quantify, but several methods have been suggested. The Polluter Pays Principle, under which such costs should be internalized by the producer and/or the user, is seldom applied (at least without regulatory assistance), and so no good estimates are available of the potential cost of damage avoided.

Given the discussion above the overall net benefit of phasing out c-OctaBDE for human health and the environment, is most likely positive.

### **Cost implications for industry**

Production was recently phased out in the EU, Norway, Switzerland, Canada and the USA. No information that indicates it is being produced in developing countries. Processing is considered zero in the EU and Canada. Some processing of c-OctaBDE may still occur in the USA but it is considered to be zero or close to zero. Appropriate substitutes for c-OctaBDE are available **and mass-production of alternatives can significantly lower their costs.**<sup>141</sup>

Canada expects no cost implications on industry for the substitution of c-PentaBDE and c-OctaBDE (Canada Gazette, 2006a). In the light of the complete ban and phase out of c-OctaBDE a similar conclusion can be made for Europe. Taking account of the voluntary phase out of c-OctaBDE in the USA additional costs are also not expected for USA industries.

Canada have also stated it is not possible to quantify and monetise the preventative (health and environment) benefits of the proposed Regulations given that PBDE use by industry has been discontinued and future demand for the substance cannot be estimated. However, costs to industry

**Comment [J24]:** A single section on costs of c-octaBDE phaseout as done in the pentaBDE RME should be considered

**Deleted:** .

<sup>141</sup> Ackerman F, Massey R. The Economics of Phasing Out PVC, Global Development and Environment Institute, Tufts University, USA, May 2006  
[http://www.ase.tufts.edu/gdae/Pubs/rp/Economics\\_of\\_PVC\\_revised.pdf](http://www.ase.tufts.edu/gdae/Pubs/rp/Economics_of_PVC_revised.pdf)

and government of the proposed regulations have been estimated. The economic criterion that was considered was the cost to industry to reformulate away from the use of PentaBDE and OctaBDE. This cost was deemed to be minor (zero) as drop-in substitutes are available, and PentaBDE and OctaBDE are no longer being manufactured, imported or used in Canada. Therefore, the industry is not expected to experience any incremental costs as a result of the regulatory requirements. Costs to government were also considered as part of the economic analysis, which included compliance promotion and enforcement activities; these costs were calculated over a 25-year time frame and estimated to be in the order of \$439,646 (discounted at 5.5%). Overall, the Regulations were estimated to result in a negative net benefit of \$439,646 (net present value discounted at 5.5%) over a 25-year time frame (UNEP, 2008 Canada).

Against this background it can be concluded that industry will not experience any incremental costs, as a result of the proposed options.

Also if a ban of c-OctaBDE will come into force it would be reasonable to implement BAT/BEP (Best Available Technologies/Best Environmental Performance) at disposal and recycling/recovery installations in order to reduce releases from products containing c-OctaBDE at disposal and recycling/recovery. Additional costs could particularly arise from technical measures to be applied at disposal, recycling/recovery and dismantling facilities. Possible technical measures are related to BAT/BEP and require economically reasonable operational and/or investment costs. Costs related to the application of BAT are per se economically viable as this term designates economically and technically available techniques. The best environmental performance is usually achieved by the installation of BAT and its operation in the most effective and efficient manner.

The installation of end-of-pipe control technologies could be costly. However, in **many** countries requirements for end-of-pipe measures already exist for disposal and recycling/reclamation plants (e.g. for off-gas cleaning in incineration plants and emission control in shredding plants). Therefore expected cost implications are limited in those countries.

Deleted: most

**For c-DecaBDE substitutes, the Danish EPA estimates that, “The prices of the copolymers with organo-phosphorous flame retardants (FRs) are about 60-70% higher than HIPS with Deca-BDE, corresponding to a price increase of the raw materials of an average TV-set with CRT technology (27.5-inch screen) of about 5 €”<sup>142</sup>**

**The State of Illinois (USA) concluded that there no significant affordability issues for alternatives to c-DecaBDE in consumer electronics, other electrical applications and electronic products, and most uses of textiles and foams.<sup>143</sup> Illinois did indicate that there were moderate affordability issues in medical and transportation uses due to the performance / safety testing and associated laboratory work required in those industries before a new design may be brought to market. The report noted that, “...many users of DecaBDE are in the process of phasing it out or intend to phase it out as soon as reasonably possible.”**

**The State of Maine (USA) estimates 57% of the TVs in the state are already c-DecaBDE-free and concludes that, “... a shift to other plastics likely will lead to a small increase in the price**

<sup>142</sup> Lassen C, Havelund S, Leisewitz A, Maxson P. COWI A/S, Denmark; Oko-Recherche BmbH, Germany; Concorde East/West Sprl, Belgium. Deca-BDE and alternatives in electrical and electronic equipment, Danish Ministry of the Environment, 200  
<http://www2.mst.dk/Udgiv/publications/2007/978-87-7052-349-3/pdf/978-87-7052-350-9.pdf>

<sup>143</sup> Illinois Environmental Protection Agency, Report on alternatives to the flame retardant decaBDE: Evaluation of toxicity, availability, affordability, and fire safety issues. A report to the Governor and State Assembly. March 2007 <http://www.epa.state.il.us/reports/decabde-study/>

of low-end TVs”.<sup>144</sup> With regard to electrical parts, the State notes that, “The fact that decaBDE is used in only about 10% of all electrical parts flame retarded with PBT and only about 6% of parts flame retarded with PA is further suggests that the cost of alternatives is not a significant barrier to use.” For mattresses, the report notes that, “...there are safer, low-cost alternatives to decaBDE.” In the area of transportation, the report states that the auto industry claims a need for five years to fully eliminate c-DecaBDE from cars and that the airplane industry might also require a long transition.

The State of Minnesota examined decaBDE alternatives and concluded that, “The cost to accomplish a phase out of Deca-BDE is concluded to be minor for the consumer electronics and textile industries.”<sup>145</sup> The report goes on to say that cost of alternatives is more of a concern in medical devices and transportation primarily due to the highly regulated nature of the industries and the extensive product testing that is required.

Within the EU, the European Commission and the UK have prepared a Risk Reduction Strategy and an analysis of advantages and drawbacks of possible measures to reduce the risks identified for the environment through the European Union Risk Assessment procedure (RPA, 2002). In the light of the ban and phase out of c-OctaBDE the analyses is not any more up-to-date, in particular the economic assessment.

#### **Cost implications for consumers**

In the RPA cost assessment it has been indicated that increased costs would be passed on to the consumer (RPA, 2002). As there will be no further increases in cost to industry, no increased cost for consumers are expected.

#### **Cost implications for state budgets**

In the EU no incremental costs for state budgets are expected in the light of the ban and phase out of c-OctaBDE as a consequence of the proposed option. Additional budgets for enforcement and compliance are not required.

Canada has performed a cost estimate for the proposed regulations on PBDEs for the costs that would be incurred by the federal government as a result of enforcement and compliance promotion activities related to the proposed Regulations. The regulatory impact analyses statement is published in the Canada Gazette (Canada Gazette, 2006a).

The key assumptions used for the analysis include the following:

- Regulatory time frame: the proposed Regulations are assumed to come into force at the end of 2007, with the ban on PentaBDE and OctaBDE imports and uses being fully in effect in 2008 when uses reach zero.
- Time frame for analysis: costs and benefits are assessed over a 25-year time frame (2007 to 2032).

---

<sup>144</sup> Maine Center for Disease Control and Prevention, Brominated flame retardants; Third report to the Maine Legislature, Maine Department of Environmental Protection (USA), 2007  
<http://www.maine.gov/dep/rwm/publications/legislativereports/pdf/finalrptjan07.pdf>

<sup>145</sup> Minnesota Pollution Control Agency, Decabromodiphenyl ether (Deca-BDE), A report to the Minnesota legislature, January 15, 2008 <http://www.pca.state.mn.us/publications/reports/lrp-ei-2sy08.pdf>

- Accounting stance: the costs and benefits assessed are those that directly or indirectly affect Canada or Canadians. All costs and benefits are in 2006 Canadian dollars<sup>146</sup>.
- Discount rate: where possible, impacts are reported as net present values and a real social discount rate of 5.5% is used.
- Risk and uncertainty testing: the key sources of uncertainty were identified and are considered in the analysis.

Total enforcement and compliance promotion costs for the Canadian Government over the 25-year time frame were reported to be in the order of \$439,646 Canadian dollars which can be split up as follows:

- With respect to enforcement costs, for the first year following the coming into force of the proposed Regulations, a one-time amount of \$250,000 will be required for the training of enforcement officers.
- In addition, for years one through five following the delivery of the training, the enforcement costs are estimated to require an annual budget of \$56,220 broken down as follows: \$37,750 for inspections (which includes operations and maintenance costs, transportation and sampling costs), \$14,330 for investigations and \$4,140 for measures to deal with alleged violations (including environmental protection compliance orders and injunctions).
- For the subsequent years (that is years 6 through 25), the enforcements costs are estimated to require a total budget of \$62,738 broken down as follows: \$27,000 for inspections (which includes operations and maintenance costs, transportation and sampling costs), \$17,642 for investigations and injunctions, and \$18,096 for prosecutions.
- Compliance promotion activities are intended to encourage the regulated community to achieve compliance with the proposed Regulations. Compliance promotion costs would require an annual budget of \$118,000 during the first year of coming into force of the proposed Regulations. Compliance promotion activities could include mailing out of the final Regulations, developing and distributing promotional materials (i.e. a fact sheet, Web material), the development of an advertising campaign in specialized trade publications, attendance at association conferences and workshops/information sessions to explain the Regulations. This could also include responding to and tracking inquiries in addition to contributing to the compliance promotion database.
- In the four years that follow, compliance promotion activities could decrease in intensity and focus on sending letters, advertising in specialized trade magazines, attending association conferences, responding to and tracking inquiries, and contributing to the compliance promotion database. This would require a budget of \$36,800. Note that a higher level of effort for compliance promotion may be required if following enforcement activities compliance with the Regulations is found to be low. For subsequent years, no additional compliance promotion activity is expected, and therefore, total compliance promotion costs are estimated at \$154,800.

To conclude, Canada expected no incremental costs for state budgets in light of the proposed regulations on PBDE as a consequence of the proposed option. Additional budgets for enforcement and compliance are not required.

<sup>146</sup> 1€ = 1.53 Canadian dollars

## Comparisons of costs and benefits

Given the conclusions of the Risk Profile (UNEP 2007) for C-OctaBDE, its widespread global occurrence in biota and in humans, action taken or underway to phase it out in developed and developing countries and the increased demand for alternatives to C-OctaBDE, the overall consequence of a full global phase-out is most likely to be positive. Overall, the cost for developed countries of a phase out of C-OctaBDE should be small, as discussed above. However, specialized waste management and disposal related to C-OctaBDE (stockpiles and articles) could be costly for some countries and financial and technical assistance to developing countries should be considered to address this aspect as required.

### 3.6 Identification and discussion of possible management options under the Stockholm Convention

#### Possible management options

The objective of the Stockholm Convention is to **protect human health and the environment from POPs while being mindful of the Precautionary Approach as set forth in Principle 15 of the Rio Declaration on Environment and Development. In practice this means measures to eliminate releases from intentional production and use such as prohibition of production, use, import, and export; measures to reduce the releases from unintentionally-produced POPs with the goal of continuing minimization and ultimate elimination; and measures to manage stockpiles and wastes in an appropriate environmentally sound manner.**

**Deleted:** control, reduce or eliminate discharges, emissions and losses of Persistent Organic Pollutants.

The main remaining emissions of c-OctaBDE occur during the service life and particularly at disposal and recycling/reclamation of products containing c-OctaBDE, however, re-introduction of the product or similar products is currently possible.

Possible management options are to restrict or eliminate production and use of c-OctaBDE or its congeners having POP characteristics. Listing the **c-octaBDE mixture but naming the individual congeners as markers for enforcement purposes** could facilitate the monitoring and control of emissions, production and use. This would also be consistent with existing national legislations. All **the components of commercial OctaBDE** mixtures would then be covered by the Convention, except when they occur as trace.

**Deleted:** containing congeners having POP characteristics

Options for the regulation of c-OctaBDE have also been discussed in the risk management evaluation of PentaBDE (UNEP, 2007d). It was suggested that, if a decision is taken to list bromodiphenyl ethers with four or five bromines, consideration should be given to also listing HexaBDE, which constitutes a small proportion of the c-PentaBDE mixture. While this has some obvious advantages, the earlier information on c-PentaBDE (including the Annex D Risk profile statement) has not included much information about the HexaBDE. Also, since HexaBDE is a component of the c-OctaBDE, listing the HexaBDE would need to be considered when evaluating management options for OctaBDE.

**Deleted:** the separate

In agreeing a risk management evaluation for c-PentaBDE, the Persistent Organic Pollutants Review Committee decided, in accordance with paragraph 9 of Article 8 of the Convention, to recommend to the Conference of the Parties that it consider listing in Annex A of the Stockholm Convention 2,2',4,4'- tetrabromodiphenyl ether (BDE-47, CAS No. 40088-47-9) and 2,2',4,4',5-pentabromodiphenyl ether (BDE-99, CAS No. 32534-81-9) and other tetra- and pentabromodiphenyl ethers present in commercial pentabromodiphenyl ether, using BDE-47 and BDE-99 as markers for enforcement purposes (UNEP 2007a).

## Discussion of options

- c-OctaBDE can be released from production, handling, compounding and conversion (processing), use of products, disposal and recycling and dismantling.

In order to achieve long term elimination and prevent re-introduction of c-OctaBDE or **components that could make up the commercial mixture**, production, use, import, and export of c-OctaBDE should be completely banned. Only this action would ensure the long term elimination of components contained in commercial BDE mixtures and would contribute to achieving maximum non-quantifiable benefits. **This would also prevent new production of c-octaBDE using different congeners of hexa-, hepta-, octa-, and nonaBDEs to formulate new c-OctaBDE mixtures.**

**Deleted:** the congeners having POP characteristics

**Deleted:** and

**Deleted:** all risks from the POP

**Components of c-OctaBDE are also unintentionally formed through debromination of higher substituted congeners, including commercial decabromodiphenyl ether (c-DecaBDE) which also has the potential for long range transport.<sup>147</sup> The POPRC has agreed that debromination is occurring in aquatic organisms, mammals, and birds and that components of c-OctaBDE are produced in the environment by debromination of c-DecaBDE.<sup>148</sup> Newer studies indicate that debromination of decaBDE and formation of c-OctaBDE congeners can occur indoors under normal ambient conditions. This indicates that control measures need to be established that address c-DecaBDE production and use to prevent further formation of components of the c-OctaBDE mixture in the environment.**

**Formatted:** Space Before: 0 pt, After: 0 pt

[A ban on the **components of the c-octaBDE mixture** would be related to the following advantages:

**Comment [J25]:** The listing approach outlined in the pentaBDE RME seems applicable here. The Committee has already invoked the precautionary language for dealing with octa and nona in the Risk Profile and governments could utilize the precise congeners as markers for enforcement purposes. If only specific hexa and hepta congeners are listed, the goal of the Convention will not be realized since huge loopholes will remain.

- *Better practicality.* Several countries have reported that they will have problems to regulate a commercial mixture of PentaBDE (UNEP 2007d). This is also valid in the case of c-OctaBDE. Most national regulations concern compounds. It will therefore be more practical to list the BDE congeners having POP characteristics. All mixtures with one of the congeners having POP characteristics will then be covered.
- *More efficient monitoring and control.* Listing the individual congeners could facilitate the monitoring and control of emissions, production and use.
- *Target oriented and long term effective.* Listing of the harmful congeners will contribute to the control of the relevant components of all commercial BDE mixtures. Even if producers will change the formulation of commercial BDE mixtures in the future it will be assured in the long term that the relevant harmful components will be banned.]

**Deleted:** BDE congeners having POP characteristics

### Proposed alternative text:

**Several countries have reported that they will have problems to regulate a commercial mixture of PentaBDE (UNEP 2007d). This is also valid in the case of c-OctaBDE. Most national regulations concern compounds. For this reason, the POPRC recommended listing tetra- and pentabromodiphenyl ethers using specific BDE congeners as markers for enforcement purposes. In a like manner for c-OctaBDE, hexa-, hepta-, octa-, and nonabromodiphenyl ether congeners could be listed and the following relevant congeners could be used as markers for enforcement purposes: BDE153 (hexaBDE); BDE175/183 (heptaBDE); BDE196, BDE197, BDE203 (octaBDE); and BDE206, BDE207 (nonaBDE). This will have several advantages. The markers will serve as precise regulatory marker to aid in**

**Comment [J26]:** Not true. This merely opens the door to formulating new octa mixtures using congeners that are not listed. Some of these are found in humans and wildlife. Later, when more thorough studies are conducted and information emerges, the process will start over with the congeners that were not covered the first time. This delays protection from POPs and is not consistent with the precautionary mandate of the Convention. The listing approach in the pentaBDE document carries the right mix of specificity for regulators and inclusiveness to meet Convention objectives.

<sup>147</sup> Risk profile on commercial octabromodiphenyl ether UNEP/POPS/POPRC.3/20/Add.6

<sup>148</sup> Risk profile on commercial octabromodiphenyl ether UNEP/POPS/POPRC.3/20/Add.6

**more efficient monitoring and control. At the same time, production and use of all components of the c-OctaBDE mixture will be prohibited in keeping with Convention objectives.**

## Synthesis of information

### 4.1 Summary of evaluation

The term “c-OctaBDE” designates a commercial mixture containing polybrominated diphenyl ethers, typically consisting of penta- to deca-bromodiphenyl ether congeners. The specific composition of older mixtures or mixtures from various countries may be different. c-OctaBDE has been used as an additive flame retardant mainly in plastics industry for polymers used for housings of office equipment. The risks it poses to human health and the environment have been explored in the Annex E Risk profile adopted by the POPRC in November 2007 (UNEP, 2007b).

There are national and international standards for fire safety for some product groups. This applies for example to electrical material, industrial packaging, upholstered furniture, curtains, electronic household appliances and electrical cables. These standards specify the flame-retarding properties that are required. Traditionally brominated flame retardants have been considered to be the most cost-effective way of imparting ignition resistance to many types of articles. However, in **many cases** these are being replaced with flame retardants without bromine, or the design of the product is changed so that there is no need for the continued use of chemical flame retardants.

Suitable and economically viable alternatives are available for all uses of c-OctaBDE. The human health or environmental impacts of these alternatives made them preferable alternatives over c-OctaBDE. However, some alternatives currently in use caused concern because of their properties. Reactive type flame retardants and halogen free substitutes appear to be generally preferable under environmental and health aspects.

**For c-DecaBDE, the Danish EPA concluded that, “This study has not identified any application of Deca-BDE in electrical and electronic equipment for which substitution is not possible, from the scientific or technical point of view. For all EEE materials and components presently using Deca-BDE, technically acceptable alternatives are available on the market. The widespread use of alternatives, and availability of EEE components without Deca-BDE, is indicated by the fact that a large number of the world’s major manufacturers of EEE have phased out the use of Deca-BDE in their products.”<sup>149</sup> The Danish EPA report estimates that, “The prices of the copolymers with organo-phosphorous flame retardants (FRs) are about 60-70% higher than HIPS with Deca-BDE, corresponding to a price increase of the raw materials of an average TV-set with CRT technology (27.5-inch screen) of about 5 €”<sup>150</sup>**

Incremental costs as a result of a complete ban are not expected for the industry.

A ban of c-OctaBDE **and c-DecaBDE** would ultimately eliminate emissions from the production, manufacturing and use in new products. It would neither affect the emissions from products already in use nor directly influence emissions from disposal or recovery. Application of BAT/BEP at

Deleted: some

Comment [J27]: The use of the word “many” is justified here since most of the top computer manufacturers have moved or are moving away from PBDEs. See above for specifics in 3.2ter

Formatted: Indent: Left: 0", Space Before: 0 pt, After: 0 pt

<sup>149</sup> Lassen C, Havelund S, Leisewitz A, Maxson P. COWI A/S, Denmark; Oko-Recherche BmbH, Germany; Concorde East/West Sprl, Belgium. Deca-BDE and alternatives in electrical and electronic equipment, Danish Ministry of the Environment, 200

<http://www2.mst.dk/Udgiv/publications/2007/978-87-7052-349-3/pdf/978-87-7052-350-9.pdf>

<sup>150</sup> Lassen C, Havelund S, Leisewitz A, Maxson P. COWI A/S, Denmark; Oko-Recherche BmbH, Germany; Concorde East/West Sprl, Belgium. Deca-BDE and alternatives in electrical and electronic equipment, Danish Ministry of the Environment, 200

<http://www2.mst.dk/Udgiv/publications/2007/978-87-7052-349-3/pdf/978-87-7052-350-9.pdf>

disposal and recycling/dismantling/reuse could be an efficient and economically reasonable way to minimise related emissions..

Costs implications for consumers are not expected **but there could be small increases for some items that currently use decaBDE**.

Deleted: .

Financial costs for Governments would depend on the management actions taken. There might be costs associated with mandated control measures e.g. monitoring and enforcement of waste management facilities. There might also be costs associated with monitoring and controlling articles containing c-OctaBDE **and c-DecaBDE**.

#### 4.2 Elements of a risk management strategy

Since the dissemination of bromodiphenyl ethers into the environment is a global, transboundary problem, some global actions to phase out c-OctaBDE should be considered. Risk management would be best served by a global ban on production and use of c-OctaBDE covering all sectors.

Listing BDEs **that are components of the c-OctaBDE mixture** under Annex A of the Stockholm Convention would be the most appropriate measure, given that most developed countries have already banned production. Developed countries have in place all monitoring and control capacities as well as legislative tools to enforce a ban. Thus, the main enforcement challenge would be for the developing countries to get sufficient capacities in place.

Deleted: congeners having POP characteristics of

**Using relevant congeners of the c-OctaBDE mixture as markers for enforcement purposes**, would be consistent with existing national legislation in several countries for components of c-OctaBDE and would facilitate the national monitoring and control of emissions, production and use.

Deleted: Listing the

Deleted: BDE congeners having POP characteristics

**The components of c-OctaBDE are unintentionally formed through debromination of higher substituted congeners, including commercial decabromodiphenyl ether (c-DecaBDE). This indicates that listing c-OctaBDE in Annex C of the Stockholm Convention with control measures that address c-DecaBDE would be an appropriate measure to prevent further formation of c-OctaBDE and other BDE congeners in the environment. In general, developed countries have in place all monitoring and control capacities as well as legislative tools to enforce a ban. Thus, the main enforcement challenge would be for the developing countries to get sufficient capacities in place.**

The provision of guidance on criteria for the selection of alternatives to c-OctaBDE **and c-DecaBDE** should be part of the risk management strategy for the elimination of this substance. It will be important to discourage the replacement of c-OctaBDE **and c-DecaBDE** with other environmentally harmful substances.

**Under the Stockholm Convention, a listing of c-OctaBDE in Annex A and Annex C would also subject wastes products or articles containing the substance to Article 6 of the Stockholm Convention and require that they be disposed, "...in a safe, efficient and environmentally sound manner."**<sup>151</sup> Waste fractions containing c-OctaBDE **and c-DecaBDE** should be handled as hazardous waste. This could impose extra costs on some countries and sectors. The solutions for waste handling should to a large extent depend on local conditions and be designed to fit into existing systems and traditions, taking the general rules of the Stockholm Convention into consideration, including the general guideline on waste handling in the Basel Convention, which includes in Annex VIII such substances as PCBs and polybromobiphenyls and 'other polybrominated analogues'.

<sup>151</sup> Stockholm Convention on Persistent Organic Pollutants, Article 6

## Concluding statement

This risk management statement has been prepared in accordance with the content specified in Annex F of the Convention, and builds on the Risk Profile adopted by the POPRC in November 2007 (UNEP, 2007b) in that **components of commercial octabromodiphenyl ether are** likely, as a result of long range environmental transport, to lead to significant adverse human health and/or environmental effects such that global action is warranted.

Deleted: some components of the

Deleted: are

In accordance with paragraph 9 of Article 8 of the Convention the Committee recommends to the Conference of the Parties to consider listing and specifying the related control measures of **hexa-, hepta-, octa-, and nonabromodiphenyl ethers** in Annex A and Annex C of the Convention, as described above, **and using BDE153 (hexaBDE); BDE175/183 (heptaBDE); BDE196, BDE197, BDE203 (octaBDE); and BDE206, BDE207 (nonaBDE) as markers for enforcement purposes.**

Deleted: PBDE) congeners having POP characteristics

Deleted: <sup>152</sup>

Deleted: .

DRAFT

## References

Arias P.A (2001): Brominated flame retardants - An overview. The Second International Workshop on Brominated Flame Retardants, BFR 2001, May 14-16, Stockholm.

BSEF [Bromine Science and Environmental Forum] (2006): [BSEF Legislative and Regulatory Activities](http://www.bsef.com/regulation/eu_legislation/index.php). From according to November 2006 update.  
[http://www.bsef.com/regulation/eu\\_legislation/index.php](http://www.bsef.com/regulation/eu_legislation/index.php)

Canada Gazette (2006a): "RoHS in China" Conformity, October 2006, p. 12-17.; Part I, Vol. 140, No 50

Canada Gazette (2006b): Canada Gazette, Part II, Vol. 140, No. 26, 27.12.2006

CANADIAN ENVIRONMENTAL PROTECTION ACT, 1999

Order Adding Toxic Substances to Schedule 1 to the Canadian Environmental Protection Act, 1999, P.C. 2006-1516, December 7, 2006

CEPA (1999): Canadian Environmental Protection Act, 1999, 1999, c. 33, C-15.31, Assented to September 14th, 1999

ECE EB (2006): ECONOMIC COMMISSION FOR EUROPE, EXECUTIVE BODY FOR THE CONVENTION ON LONG-RANGE TRANSBOUNDARY AIR POLLUTION Working Group on Strategies and Review Thirty-eighth session Geneva, 19–22 September 2006 Item 4 of the provisional agenda, ECE/EB.AIR/WG.5/2006/10, 26 July 2006

Environment Canada (2006a): Canadian Environmental Protection Act, 1999, Ecological Screening Assessment Report on Polybrominated Diphenyl Ethers (PBDEs), Environment Canada, June 2006

Environment Canada (2006b): Canadian Environmental Protection Act, Supporting Working Document for the Environmental Screening Assessment of Polybrominated Diphenyl Ethers, Government of Canada, Environment Canada, June 2006

European Commission (2000): Di-(2-ethylhexyl) phthalate. European Commission (EC), European Chemicals Bureau, Draft Risk Assessment Report, May 2000 version, (Internet publication at <http://ecb.jrc.it/>).

European Commission (2002): European Union Risk Assessment Report. Bis(pentabromophenyl)ether (CAS No: 1163-19-5, EINECS No: 214-946-9). RISK ASSESSMENT. Office for Official Publications of the European Communities, 2003. publication at <http://ecb.jrc.it/>

European Commission (2003a): European Union Risk Assessment Report. DIPHENYL ETHER, OCTABROMO DERIVATIVE (CAS No: 32536-52-0, EINECS No: 251-087-9). RISK ASSESSMENT. Office for Official Publications of the European Communities, 2003. publication at <http://ecb.jrc.it/>

European Commission (2003b): Technical Guidance Document on Risk Assessment in support of Commission Directive 93/67/EEC on Risk assessment for new notified substances, Commission Regulation (EC) 1488/94 on Risk assessment for existing substances and Directive 98/8/EC of the European Parliament and of the Council concerning the placing of biocidal products on the market. Parts 1-4. 2nd edition. European Commission, 2003. publication at <http://ecb.jrc.it/>

European Commission (2005): Risk Profile and Summary Report for Octabromodiphenyl ether (octaBDE); Dossier prepared for the UNECE Convention on Long Range Transboundary Air

Pollution, Protocol on Persistent Organic Pollutants European Commission, DG Environment, August 2005

European Commission (2006): Integrated Pollution Prevention and Control, Reference Document on Best Available Techniques for the Waste Treatments Industries, August 2006

European Union (2000): Directive 2000/60/EC of the European Parliament and of the Council of 23 October 2000 establishing a framework for Community action in the field of water policy. OJ L327, 22/12/2000, p. 1 – 72.

European Union (2002a): Directive 2002/95/EC of the European Parliament and of the Council of 27 January 2003 on the restriction of the use of certain hazardous substances in electrical and electronic equipment OJ L037, 13/02/2003 p. 0019 – 0023.

European Union (2002b): Directive 2002/96/EC of the European Parliament and of the Council of 27 January 2003 on waste electrical and electronic equipment (WEEE) OJ L 037, 13/02/2003 p. 0024 – 0039.

European Union (2003): Directive 2003/11/EC of the European Parliament and of the Council of 6 February 2003 amending for the 24th time Council Directive 76/769/EEC relating to restrictions on the marketing and use of certain dangerous substances and preparations (pentabromodiphenyl ether, octabromo-diphenyl ether) OJ L 42 15.2.2003 45-46.

KEMI (1994): Risk Assessment of Polybrominated Diphenyl Ethers. The Swedish National Chemicals Inspectorate, Solna, Sweden, 1994.

INERIS (2006) Données technico-économiques sur les substances chimiques en France, OCTA BROMOS DIPHENYLEETHERS, Dernière mise à jour : 03/08/2006. Available at [http://rsde.ineris.fr/fiches/fiche\\_octaBromoDiphenylEthers.pdf](http://rsde.ineris.fr/fiches/fiche_octaBromoDiphenylEthers.pdf)

OECD, 1994. Selected brominated flame retardants. Risk Reduction Monograph No. 3, OECD Environment Monograph Series No. 102, Paris.

RPA (2001) Octabromodiphenyl ether: Risk Reduction Strategy and Analysis of Advantages and Drawbacks. Draft Stage 2 Report prepared for Department for Environment, Food and Rural Affairs. Risk and Policy Analysts Limited, November 2001.

RPA (2002) Octabromodiphenyl ether: Risk Reduction Strategy and Analysis of Advantages and Drawbacks. Final report. Report prepared for Department for Environment, Food and Rural Affairs. Risk and Policy Analysts Limited, June 2002. [http://www.defra.gov.uk/environment/chemicals/pdf/octa\\_bdpe\\_rrs.pdf](http://www.defra.gov.uk/environment/chemicals/pdf/octa_bdpe_rrs.pdf)

SAEFL (2002) ENVIRONMENTAL SERIES No. 338, Environmentally hazardous substances, Selected polybrominated flame retardants PBDE and TBBPA, Substance flow analysis, Published by the Swiss Agency for the Environment, Forests and Landscape (SAEFL), Bern, 2002

Switzerland (2005): Ordinance on Risk Reduction related to Chemical Products of 18 May 2005. <http://www.bafu.admin.ch/chemikalien/01410/01411/index.html?lang=en&download=NHzLpZig7t,lnp6I0NTU042I2Z6lnlad1IZn4Z2qZpnO2YUq2Z6gpJCEeIB2gGym162dpYbUzd,Gpd6emK2Oz9aG0detmqaN19XI2IdvoaCVZ,s-.pdf>

UBA (2003a) Leitfaden zur Anwendung umweltverträglicher Stoffe für die Hersteller und gewerblichen Anwender gewässerrelevanter Chemischer Produkte, TEIL 3, Produktspezifische Strategie, Additive in Kunststoffen, Umweltbundesamt, Februar 2003

UBA (2003b) Leitfaden zur Anwendung umweltverträglicher Stoffe für die Hersteller und gewerblichen Anwender gewässerrelevanter Chemischer Produkte, TEIL 5, Hinweise zur Substitution gefährlicher Stoffe, 5.2 Funktion: Flammschutzmittel, Umweltbundesamt, Februar 2003

UK (2007) CMR, PBT, vPvB Proposal. Annex XV, Proposal for identification of a substance as a CMR, PBT, vPvB or a substance of an equivalent level of concern, UK 2007

UNECE Survey (2007) Convention on Long Range Transboundary Air Pollution, Working Group on Strategies and Review Task Force on POPs, Responses to the questionnaire on management options for reducing production, use and emissions of Persistent Organic Pollutants (POPs) under the 1998 Protocol on POPs, 5 February 2007; Responses related to c-octaBDE submitted in March 2007 by BE, CZ, CY, DE, NL, FR, IT, UK, CH, USA, and BSEF

UNEP (2007a) Annex I decision: commercial octabromodiphenyl ether. Stockholm Convention on Persistent Organic Pollutants: Persistent Organic Pollutants Review Committee, Third Meeting, Geneva 19-23 November 2007. UNEP/POPS/POPRC.3/20 Decision/POPRC-3/6.

UNEP (2007b) Adopted risk profile on commercial octabromodiphenyl ether. Stockholm Convention on Persistent Organic Pollutants: Persistent Organic Pollutants Review Committee, Third Meeting, Geneva 19-23 November 2007. UNEP/POPS/POPRC.3/20/Add.6.

UNEP (2007c) Annex E responses to request for information on Annex E requirements for the proposed POPs substances which have been submitted in 2007 to the Persistent Organic Pollutants Review Committee (POPRC) under the Stockholm Convention. Responses available at <http://www.pops.int/documents/meetings/poprc/prepdocs/annexEsubmissions/submissions.htm>

UNEP (2007d) Draft risk management evaluation: pentabromodiphenyl ether. Stockholm Convention on Persistent Organic Pollutants: Persistent Organic Pollutants Review Committee, Third Meeting, Geneva 19-23 November 2007. UNEP/POPS/POPRC.3.9.

UNEP (2008) Annex F responses to request for information on Annex F requirements for the proposed POPs substances which were submitted in 2008 to the Persistent Organic Pollutants Review Committee (POPRC) under the Stockholm Convention. Responses available at ([http://www.pops.int/documents/meetings/poprc/AnnexF\\_submission\\_2008.htm](http://www.pops.int/documents/meetings/poprc/AnnexF_submission_2008.htm)). Responses related to c-octaBDE submitted in March 2007 by Armenia, Bromine Science and Environmental Forum (BSEF), Canada, Czech Republic, International POPs Elimination Network, Monaco, Netherlands, Norway, United States.

US EPA (2003a): Brominated Flame Retardants To Be Voluntarily Phased Out. Release date: 11/03/2003. <http://yosemite.epa.gov/opa/admpress.nsf/3e60b0f437cbc2f1852570180055f2dd/26f9f23c42cd007d85256dd4005525d2!OpenDocument>

US EPA (2003b): Voluntary Children's Chemical Evaluation Program (VCCEP), Tier 1, Assessment of the potential health risks to children associated with the exposure to the commercial octabromodiphenyl ether product, CAS No. 32536-52-0, April 2003. See <http://tera.org/peer/vccep/OctaPenta/OctaPentaWelcome.html>

US EPA (2006): TSCA Significant New Use Rule: 71 FR 34015, June 13, 2006; 40 CFR 721.10000

Watanabe and Tatsukawa (1990): Watanabe I and Tatsukawa R. Anthropogenic brominated aromatics in the Japanese environment. In "Proceedings of Workshop on Brominated Aromatic Flame Retardants, Skokloster, Sweden, 24-26 October, 1989", 1990.

WHO (1994): Environmental Health Criteria 162: Brominated Diphenyl Ethers. International Programme on Chemical Safety (IPCS), World Health Organization, Geneva, 1994.

- <sup>1</sup> Eriksson J, Jakobsson E, Marsh G, Bergman Å. (2001). Photo decomposition of brominated diphenyl ethers in methanol/water. Abstracts. The Second International Workshop on Brominated Flame Retardants. BFR 2001 Stockholm. May 14-16. Stockholm University, Sweden. p. 203-206
- <sup>2</sup> Eriksson J, Green, N, Marsh G, Bergman, A. (2004) Photochemical decomposition of 15 polybrominated diphenyl ether congeners in methanol/water. *Environmental Science & Technology* 38:3119-3125
- <sup>3</sup> Fang L, Huang J, Yu G, Wang L. (2007) Photochemical degradation of six polybrominated diphenyl ether congeners under ultraviolet irradiation in hexane, *Chemosphere* 71:258-267
- <sup>4</sup> Bezares-Cruz J, Jafvert CT, Hua I. (2004) Solar Photodecomposition of Decabromodiphenyl Ether: Products and Quantum Yield. *Environ. Sci. Technol* 38:4149 -4156
- <sup>5</sup> Soderstrom, G, Sellstrom U, De Wit CA, Tysklind M. (2004) Photolytic debromination of decabromodiphenyl ether (BDE 209). *Environmental Science & Technology* 38:127-132
- <sup>6</sup> Sanchez-Prado, L., Lores, M., Llompart, M., Garcia-Jares, C., Bayona, J.M. and Cela, R. (2006), 'Natural sunlight and sun simulator photolysis studies of tetra- to hexa-brominated diphenyl ethers in water using solid-phase microextraction', *J Chromatogr. A*. 1124:157-66
- <sup>7</sup> Rayne, S., Wan, P. and Ikonou, M. (2006), 'Photochemistry of a major commercial polybrominated diphenyl ether flame retardant congener: 2,2',4,4',5,5'-hexabromodiphenyl ether (BDE153)', *Environ Int.* 32:575-85
- <sup>8</sup> Stapleton HM, Dodder NG (2008) 'Photodegradation of decabromodiphenyl ether in house dust by natural sunlight' *Environ Toxicol Chem* 27:306-312
- <sup>9</sup> Allen JG, McClean MD, Stapleton HM, Webster TF, (2008) *Environ Int* In press
- <sup>10</sup> Gerecke, A.C., Hartmann, P.C., Heeb, N.V., Kohler, H-P. E., Giger, W., Schmid, P., Zennegg, M. and Kohler, M. (2005), 'Anaerobic Degradation of Decabromodiphenyl Ether', *Environ. Sci. Technol.* 39, 1078-1083
- <sup>11</sup> He, J., Robrock, K.R. and Alvarez-Cohen, L. (2006). 'Microbial Reductive Debromination of Polybrominated Diphenyl Ethers (PBDEs)', *Environ. Sci. Technol.* 40: 4429-4434
- <sup>12</sup> Schaefer, E. C. and Flaggs, R. (2001), 'Potential for biotransformation of radiolabelled tetrabromodiphenyl oxide (TeBDPO) in anaerobic sediment. Final Report. Project 439E-105. Wildlife International, Ltd. Easton, MD
- <sup>13</sup> Schaefer, E. C. and Flaggs, R. (2001a), 'Potential for biotransformation of radiolabelled decabromodiphenyl oxide (DBDPO) in anaerobic sediment. Final Report. Project 439E-104. Wildlife International, Ltd. Easton, MD
- <sup>14</sup> Auer, C.M., US EPA, to Sandrof, N., American Chemistry Council, 28 August 2006 ([www.epa.gov/oppt/vccep/pubs/ltr8282006.pdf](http://www.epa.gov/oppt/vccep/pubs/ltr8282006.pdf))
- <sup>15</sup> Stapleton, H.M., Letcher, R.J. and Baker, J.E. (2004), 'Debrominated Diphenyl Ether Congeners BDE 99 and BDE 183 in the Intestinal Tract of the Common Carp (*Cyprinus carpio*)', *Environ. Sci. Technol.* 38: 1054-1061
- <sup>16</sup> Tomy, G.T., Palace, V.P., Halldorson, T., Braekvelt, E., Danell, R., Wautier, K., Evans, B., Brinkworth, L. and Fisk, A.T. (2004), 'Bioaccumulation, biotransformation, and biochemical effects of brominated diphenyl ethers in juvenile lake trout (*Salvelinus namaycush*)', *Environ. Sci. Technol.* 38:1496-504
- <sup>17</sup> Qiu, X., Mercado-Feliciano, M., Bigsby, R.M. and Hites, R.A. (2007), 'Measurement of Polybrominated Diphenyl Ethers and metabolites in Mouse Plasma after Exposure to a Commercial Pentabromodiphenyl Ether Mixture', *Environ. Health Perspectives*, 115(7) 1052-1058
- <sup>18</sup> Kierkegaard, A., Asplund, L., De Wit, C., McLachlan, M.S., Thomas, G.O., Sweetman, A.J. and Jones, K.C. (2007), 'Fate of Higher Brominated PBDEs in Lactating Cows', *Environ. Sci. Technol.* 41, 417-423
- <sup>19</sup> Viberg, H., Fredricksson, A., Jakobsson, E., Orn, U. and Eriksson, P. (2003), 'Neurobehavioural derangements in adult mice receiving decabrominated diphenyl ether (PBDE 209) during a defined period of neonatal brain development' *Toxicol. Sci.*, 76: 112-120
- <sup>20</sup> Van den Steen, E., Covaci, A., Jaspers, V.L., Dauwe, T., Voorspoels, S., Eens, M. and Pinxten, R. (2007), 'Accumulation, tissuespecific distribution and debromination of decabromodiphenyl ether (BDE 209) in European starlings (*Sturnus vulgaris*)', *Environ. Pollut.* 148: 648-653
- <sup>21</sup> La Guardia, M.J., Hale, R.C. and Harvey, E. (2007), 'Evidence of Debromination of Decabromodiphenyl Ether (BDE-209) in Biota from a wastewater Receiving Stream', *Environ. Sci. Technol.* 41 (19), 6663-6670

- <sup>22</sup> Da Chen, Mai, B., Song, J., Sun, Q., Luo, Y., Luo, X., Zeng, E. and Hale, R.C. (2007) 'Polybrominated Diphenyl Ethers in Birds of Prey from Northern China', *Environ. Sci. Technol.* 41(6), 1828-1833
- <sup>23</sup> Verreault, J., Gebbink, W.A., Gauthier, L.T., Gabrielsen, G.W. and Letcher, R.J. (2007), 'Brominated Flame Retardants in Glacous Gulls from the Norwegian Arctic: More than Just an Issue of Polybrominated Diphenyl Ether', *Environ. Sci. Technol.* 41: 4925-4931
- <sup>24</sup> Yi Wan, Jianying Hu, Kun Zhang and Lihui An (2008), 'Trophodynamics of Polybrominated Diphenyl Ethers in the Marine Food Web of Bohai Bay, North China', *Environ. Sci. Technol.*, 42: 1078-1083
- <sup>25</sup> Morck A, Hakk H, Orn U, Klasson WE (2003) 'Decabromodiphenyl ether in the rat: absorption, distribution, metabolism, and excretion', *Drug Metab Dispos* 31: 900 - 907
- <sup>26</sup> Huwe JK, Smith DJ (2007) 'Accumulation, whole-body depletion, and debromination of decabromodiphenyl ether in male Sprague - Dawley rats following dietary exposure' *Environ Sci Technol* 41:2372-2377
- <sup>27</sup> Riu A, Cravedi JP, Debrauwer L, Garcia A, Canlet C, Jouanin I, Zalko D (2008) Disposition and metabolic profiling of [(14)C]-Decabromodiphenyl ether in pregnant Wistar rats. *Environ Int* 34:318-329
- <sup>28</sup> Thuresson K, Bergman A, Jakobsson K. (2005) Occupational exposure to commercial decabromodiphenyl ether in workers manufacturing or handling flame-retarded rubber. *Environ Sci Technol* 39:1980 - 1986
- <sup>29</sup> Thuresson K, Hoglund P, Hagmar L, Sjodin A, Bergman A, Jakobsson K. (2006) Apparent half-lives of hepta- to decabrominated diphenyl ethers in human serum as determined in occupationally exposed workers. *Environ Health Perspect* 114:176 - 181
- <sup>30</sup> Johnson-Restrepo B, Kannan K, Addink R, Adams DH, Polybrominated diphenyl ethers and polychlorinated biphenyls in a marine foodweb of coastal Florida. *Environmental Science & Technology* 2005, 39, (21), 8243-8250
- <sup>31</sup> Bixian M, Song J, Suin Q, Zeng E, Hale RC. Polybrominated Diphenyl Ethers in Birds of Prey Collected from Northern China, SETAC, Montreal, Quebec, 2006; Montreal, Quebec, 2006
- <sup>32</sup> Christensen JR, Macduffee M, Macdonald RW, Whitticar M, Ross PS. Persistent organic pollutants in British Columbia grizzly bears: Consequence of divergent diets. *Environmental Science & Technology* 2005, 39, (18), 6952-6960
- <sup>33</sup> Kierkegaard A, Balk L, Tjarnlund U, De Wit CA, Jansson B. Dietary uptake and biological effects of decabromodiphenyl ether in rainbow trout (*Oncorhynchus mykiss*). *Environmental Science & Technology* 1999, 33, (10), 1612-1617
- <sup>34</sup> Stapleton HM, Alae M, Letcher RJ, Baker JE. Debromination of the flame retardant decabromodiphenyl ether by juvenile carp (*Cyprinus carpio*) following dietary exposure. *Environmental Science & Technology* 2004, 38, (1), 112-119
- <sup>35</sup> Tomy GT, Palace VP, Halldorson T, Braekevelt, E, Danell R, Wautier K, Evans B, Brinkworth L, Fisk AT. Bioaccumulation, biotransformation, and biochemical effects of brominated diphenyl ethers in juvenile lake trout (*Salvelinus namaycush*). *Environmental Science & Technology* 2004, 38, (5), 1496-1504
- <sup>36</sup> Morck A, Hakk H, Orn U, Wehler EK. Decabromodiphenyl ether in the rat: Absorption, distribution, metabolism, and excretion. *Drug Metabolism and Disposition* 2003, 31, (7), 900-907
- <sup>37</sup> Stapleton, H. Brominated Flame Retardants: Assessing DecaBDE Debromination in the Environment. Health and Environment Alliance, [www.env-health.org](http://www.env-health.org), May 2006
- <sup>38</sup> Christensen JR, Macduffee M, Macdonald RW, Whitticar M, Ross PS. Persistent organic pollutants in British Columbia grizzly bears: Consequence of divergent diets. *Environmental Science & Technology* 2005, 39, (18), 6952-6960
- <sup>39</sup> Voorspoels S, Covaci A, Lepom P, Escutenaire S, Schepens P. Remarkable findings concerning PBDEs in the terrestrial top-predator red fox (*Vulpes vulpes*). *Environmental Science & Technology* 2006, 40, (9), 2937-2943
- <sup>40</sup> Stapleton H. Summary of Scientific Studies on Accumulation and Debromination of DecaBDE. Health and Environment Alliance, [www.env-health.org](http://www.env-health.org), December 2006
- <sup>41</sup> Hites R. Polybrominated Diphenyl Ethers in the Environment and in People: A Meta-Analysis of Concentrations. *Environ. Sci. Technol.* 38 (4): 945-56
- <sup>42</sup> Hites, R. op cit.; WWF UK ContaminATIOn: National Biomonitoring Survey 2003 <http://www.wwf.org.uk/filelibrary/pdf/biomonitoringresults.pdf>
- <sup>43</sup> Schecter A, Vuk MP, Papke O, Ryan, JJ, Birnbaum L, Rosen, R. Polybrominated diphenyl ethers (PBDEs) in US mothers' milk. *Environmental Health Perspectives* 2003, 111, (14), 1723-1729
- <sup>44</sup> Schecter A, Papke O, Harris, TR, Tung, KC. Partitioning of polybrominated diphenyl ether (PBDE) congeners in human blood and milk. *Toxicological & Environmental Chemistry* 2006, 88, (2), 319-324
- <sup>45</sup> Jakobsson K, Thuresson K, Rylander L, Sjodin A, Hagmar L, Bergman A. Exposure to polybrominated diphenyl ethers and tetrabromobisphenol A among computer technicians. *Chemosphere.* 2002 Feb;46(5):709-16

The German Environmental Protection Agency has published a guidance document for the application of environmentally safe substances which focuses on substitution of PBDEs. The study focuses on substitution of c-decaBDE but it is stated that the results can be used for the substitution of other additive type flame retardants (UBA, 2003b).

It has to be differentiated between flame retardants of the additive type that are physically combined with the material being treated rather than chemically combined, as in reactive flame retardants (such as usually TBBP-A or specific esters of phosphoric acid). Additive type flame retardants may migrate and diffuse out of the treated material to some extent. Usually additive type flame retardants are used in thermoplastic material (e.g. Polypropylen, Polyethylen, Ethylen-Vinylacetate, PVC). They can be applied ex post to the raw polymer. Reactive type flame retardants are usually used in thermosetting material (e.g. polyester resins, epoxy resins, polyurethanes).

Generally it is considered that a substitution by additive type flame retardants that are PBT (i.e. Persistent, Bioaccumulative and Toxic) such as PBDEs, SCCPs (short chain chlorinated paraffin), MCCPs (medium chain chlorinated paraffin) or additive TBBP-A is related to a higher risk of release to the environment during use and disposal of products – irrelevant whether they contain halogens, nitrogen or phosphorus – compared to reactive type flame retardants. Halogenated flame retardants are in addition related to the risk to generate non-desired reaction products in the case of fires (UBA, 2003b).

The use of halogenated flame retardants in the EU is significantly decreasing (with the exception of chlorinated phosphoric esters). Mineral type flame retardants such as Aluminum-tri-hydroxide (ATH) or Magnesium-hydroxide or Nitrogen containing flame retardants (e.g. melamin derivatives) show significant increases. An important driving force for these market adjustments is the consideration of environmental risks (UBA, 2003b).

Halogen free flame retardants are suitable substitutes in many relevant cases. In electric and electronic equipment an efficient flame retardancy of used plastics is important. Approximately 25 % of all plastic components in this sector are flame retarded. The main share thereof is thermoplastic housings, followed by thermosetting printed circuit boards and electronic small parts. For thermoplastic housings suitable and efficient substitutes are available. In injection moulding for thermoplastic housings the fluidness is a critical parameter. Therefore mineral type flame retardants are not appropriate substitutes. Suitable alternatives that have to be evaluated in each single case are (according to UBA, 2003b) for example:

halogen free systems on phosphorus-organic basis (organic triaryl- and biphosphates such as phenylcresylphosphate mixtures, triphenylphosphate, resorcinolbisdiphenylphosphate or bisphenol-A-diphenylphosphate for PC/ABS and high-impact HIPS housings).

brominated systems with low dioxin/furan formation potential, in particular with respect to recycling/recovery processes (e.g. 1,2-bis(pentabromophenyl)ethane or ethylenbistetra-bromophthalate).

It has to be noted that the halogen free systems based on organophosphorus compounds cannot be generally considered to be the environmentally preferable substitute. However, the ecologic advantages outweigh the disadvantages at least in comparison with decaBDE or additive TBBP-A if

substances that have been sufficiently tested for toxicological properties and have proven degradability and low volatility are used as additive type flame retardant in these systems or

organophosphates that have been sufficiently tested for toxicological properties are used as reactive type flame retardant.

In the guidance document the technical practicality of substitution is demonstrated by means of several examples (UBA, 2003b).

UBA 2003a contains a comparison of 9 typical flame retardants in plastic materials and considerations on possible adverse effects: decaBDE, TBBP-A (additive), hexabromocyclodecane, tris(chloropropyl)phosphate, antimony trioxide, aluminum trihydroxide, ammonium polyphosphate, resorcinol bis(diphenyl)phosphate and zinc borate. The comparison takes health (mutagenicity, genotoxic carcinogenicity, reprotoxicity, carcinogenicity, and allergic effects) and environmental (persistence, bioaccumulation and aquatic toxicity) aspects into consideration. There is no unambiguous result that enables to determine the most appropriate flame retardant. Ammonium polyphosphate has neither CMR (Carcinogenic, Mutagenic, and Reprotoxic) nor PBT (Persistence, Bioaccumulation, Toxicity) properties but has restricted practicability due to technical reasons. This underlines the need that the evaluation has to be done on a case by case basis. However, CMR and PBT substances should generally not be used, except if their potential release is proven to be negligible.