

Stockholm Convention on Persistent Organic Pollutants

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

DRAFT RISK MANAGEMENT EVALUATION

For

Hexabromobiphenyl

Draft prepared by:

The ad hoc working group on hexabromobiphenyl

May, 2007

Draft Risk Management Evaluation for Hexabromobiphenyl

Note:

In accordance with the procedure laid down in Article 8 of the Stockholm Convention, this draft was prepared by the Persistent Organic Pollutants Review Committee (POPRC) during its inter-sessional 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 third meeting of the POPRC (19-23 November in Geneva). Please submit your comments to the Secretariat of the Stockholm Convention preferably by e-mail before **July 1, 2007** 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

Ad hoc working group on hexabromobiphenyl

Chair: Mr. Wayne Rajkumar (Trinidad and Tobago)

Drafter: Ms. Leena Ylä-Mononen (designated by the United Kingdom)

Members: Mr. Ian Rae (Australia), Mr. Robert Chénier (Canada), Mr. Mohammed Ali (Ethiopia), Mr. Reiner Arndt (Germany), Mr. Mohammed Yadallee (Mauritius), Ms. Al-Easa, Hala Sultan (Qatar), Mr. José Tarazona (Spain)

Observers: Mr. Lee Eeles (Australia), Mr. Timo Seppälä (Finland), Ms. Indrani Chandrasekharan (India), Mr. Dzierzanowski (Poland), Ms. Bettina Hitzfeld (Switzerland), Ms. Sekai Ngarize (United Kingdom), Mr. Chris Blunck (USA), Mr. Alan Rush (USA), Mr. Sylvain Bintein (EC), Ms. Mariann Lloyd-Smith (IPEN), Mr. Joseph DiGangi (EHF), Mr. Mark Trewhitt (CropLife Int.)

This draft risk management evaluation is based on the draft prepared by
European Commission, Brussels.

Table of Contents

1	Introduction.....	2
1.1	Chemical identity, production and uses.....	2
1.1.1	Chemical identity	2
1.1.2	Production and uses.....	3
1.2	Conclusions of the Review Committee regarding Annex D and Annex E information	3
1.3	Data sources.....	4
1.4	Status of the chemical under international conventions.....	5
1.5	Any national or regional control actions taken.....	6
2	Identification of possible control measures.....	7
2.1	Alternatives	7
2.1.1	Description of alternatives (substances).....	10
2.1.2	Description of alternatives (technologies).....	13
2.1.3	Technical feasibility	13
2.1.4	Costs, including environmental and health costs	13
2.1.5	Efficacy	14
2.1.6	Availability	14
2.1.7	Accessibility	14
2.2	Efficacy and efficiency of possible control measures in meeting risk reduction goals	14
2.2.1	Technical feasibility	14
2.2.2	Costs, including environmental and health costs	15
2.3	Summary of information on impacts on society of implementing possible control measures.....	16
2.3.1	Health, including public, environmental and occupational health	16
2.3.2	Agriculture, including aquaculture and forestry	16
2.3.3	Biota (biodiversity)	16
2.3.4	Economic aspects	16
2.3.5	Movement towards sustainable development	16
2.3.6	Social costs	17
2.3.7	Other impacts (Waste and disposal implications- stocks, contaminated sites).....	17
2.4	Other considerations.....	18
2.4.1	Access to information and public education	18
2.4.2	Status of control and monitoring capacity.....	18
3	Synthesis of information	19
	References	21

1 Introduction

The European Community and its Member States being Parties to the Stockholm Convention have proposed Hexabromobiphenyl to be listed in Annex A of the Stockholm Convention.

1.1 Chemical identity, production and uses

1.1.1 Chemical identity

Hexabromobiphenyl belongs to a wider group of polybrominated biphenyls (PBBs). The term “polybrominated biphenyls” or “polybromobiphenyls” refers to a group of brominated hydrocarbons formed by substituting hydrogen with bromine in biphenyl. The hexabromo congeners exist as 42 possible isomeric forms, which are listed with CAS and IUPAC numbers in US ATSDR (2004) and in document INF 2 (cited from UNEP 2006)

CAS chemical name: Hexabromo-1,1'-biphenyl

Synonyms: Hexabromobiphenyl; Biphenyl, hexabromo;
1,1'-biphenyl, hexabromo -; HBB

Trade names: FireMaster(R) BP-6; FireMaster(R) FF-1

Technical grade PBBs (FireMaster^(R)) contain several PBB compounds, isomers and congeners, Hexabromobiphenyl being one of the main components.

The composition of FireMaster^(R) BP-6 changes from batch to batch, but its main constituents are 2,2',4,4',5,5'-hexabromobiphenyl (60-80%), and 2,2',3,4,4',5,5'-heptabromobiphenyl (12-25%) together with lower brominated compounds. Mixed bromochlorobiphenyls and polybrominated naphthalenes have also been observed as minor components of FireMaster^(R) (EHC 152 (IPCS, 1994)).

FireMaster FF-1 (white powder) is FireMaster BP-6 (brown flakes) to which 2% calcium silicate has been added as an anti-caking agent (EHC 152 (IPCS, 1994)).

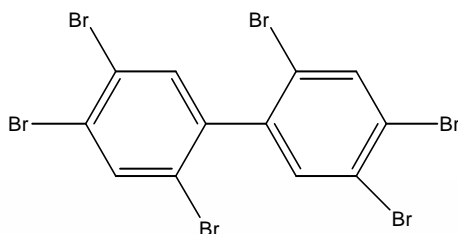
Additional data on the composition of identified PBB congeners in FireMaster^(R) BP-6 and FireMaster(R) FF-1 is given in US ATSDR (2004).

CAS registry number: 36355-01-8¹ (Common CAS number for hexabromobiphenyl isomers)
59536-65-1 Firemaster (R) BP-6 (EHC 192 (IPCS, 1997))
67774-32-7 FireMaster(R) FF-1 (EHC 192 (IPCS, 1997))

The structure of 2,2',4,4',5,5' hexabromobiphenyl (CAS No. 59080-40-9, PBB congener No. 153) is illustrated in Figure 1-1 (Structural formula source: EHC 192 (IPCS, 1997))

¹ The CAS registry number 36355-01-8 is given as a generic CAS number for PBBs in the 1988 EU Export-Import Regulation and the UNEP Rotterdam Convention.

Figure 1-1: Structural formula of 2,2',4,4',5,5' hexabromobiphenyl



1.1.2 Production and uses

According to the Risk Profile on Hexabromobiphenyl, the commercial production of PBBs began in 1970. Approximately 6 million kg of PBBs were produced in the United States from 1970 to 1976. Hexabromobiphenyl constituted about 5.4 million kg (ca 88%) of this total (Neufeld et. al., 1977 quoted from UNEP 2006). The production in the USA stopped in 1975 (Quoted from US ATSDR, 2004). Re-initiation of manufacture of PBBs would require approval from the EPA (Quoted from US ATSDR, 2004).

According to the information available, production and use of Hexabromobiphenyl has ceased in most, if not all, countries. However, it is possible that Hexabromobiphenyl is still being produced in some developing countries or in countries with economies in transition.

In the United States and Canada, Hexabromobiphenyl was used as a fire retardant in three main commercial products: acrylonitrile-butadiene-styrene (ABS) thermoplastics for constructing business machine housings and in industrial (e.g. motor housing), and electrical (e. g. radio and TV parts) products; as a fire retardant in coatings and lacquers; and in polyurethane foam for auto upholstery (Neufeld et. al., 1977 quoted from UNEP 2006) (Modified from EHC 152 (IPCS, 1994) and US ATSDR, 2004).

Approximately 5 million tonnes of Hexabromobiphenyl were produced in the USA from 1970 to 1976 (Hesse and Powers, 1978 quoted from UNEP 2006). Of the estimated 2,200 tonnes Hexabromobiphenyl produced in 1974 (IARC, 1978), about 900 tonnes were used in ABS plastic products and an even larger amount in cable coatings. The exact quantity used in polyurethane foam for automobile upholstery was not published. The two larger consumers ceased using Hexabromobiphenyl (one of these in 1972) because PBBs did not decompose in the ultimate incineration of scrapped automobiles (Neufeld et. al., 1977 quoted from UNEP 2006) (Quoted from EHC 152 (IPCS, 1994)).

1.2 Conclusions of the Review Committee regarding Annex D and Annex E information

The Committee has conducted and evaluated a risk profile in accordance with Annex E at its second meeting in Geneva 6-10 November 2006 based on the risk profile for Hexabromobiphenyl and has concluded (Decision POPRC-2/3) that, in accordance with paragraph 7 (a) of Article 8 of the Convention, Hexabromobiphenyl is likely, as a result of its long-range environmental transport, to lead to significant adverse human health and environmental effects such that global action is warranted. The Committee nevertheless requested the ad hoc working group which prepared the risk profile on Hexabromobiphenyl to

refine the risk profile further by providing estimations of the risks to human health and the environment from exposure to Hexabromobiphenyl, which should include the potential risk associated with the presence of Hexabromobiphenyl in articles and wastes. The Committee decided furthermore, 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 the Stockholm Convention, to establish an ad hoc working group to prepare a risk management evaluation that includes an analysis of possible control measures for Hexabromobiphenyl in accordance with Annex F of the Convention and invited, in accordance with paragraph 7 (a) of Article 8 of the Convention, Parties and observers to submit to the Secretariat before 2 February 2007 the information specified in Annex F for Hexabromobiphenyl and further information to allow refinement of the hazard assessment and the risk profile of Hexabromobiphenyl.

1.3 Data sources

The Risk Management evaluation is primarily based on information that has been provided by Parties to the Convention and Observers. Responses regarding the information specified in Annex F of the Stockholm Convention (risk management) have been provided by the following countries:

Table 1-1: Annex F questionnaires delivered by April 2007

Party	Institution	Date of submission
Canada	Environment Canada	08.02.2007
Czech Republic	Ministry of Environment	06.02.2007
Germany	Federal Environmental Agency	07.02.2007
Mauritius	Government	29.01.2007
Monaco	Government, Department for Environment	Not available
Thailand	Ministry of Public Health, Hazardous Substance Control Group	16.02.2005
Zambia	Environmental Council from Government of Zambia	31.01.2007
Switzerland	Federal Office for the Environment	06.02.2007
Country Observer	US EPA	09.02.2007
NGO Observer	IPEN	08.02.2007

Besides answers to the questionnaire major information sources used have been the following:

- (Danish EPA, 1999) Danish Environmental Protection Agency, Brominated flame retardants: Substance flow analysis and assessment of alternatives, June 1999. Available at http://www2.mst.dk/common/Udgivramme/Frame.asp?pg=http://www2.mst.dk/udgiv/Publications/1999/87-7909-416-3/html/kap08_eng.htm
- (USEPA, 2005), Environmental Profiles of Chemical Flame-Retardant Alternatives for Low-Density Polyurethane Foam. Available at <http://www.epa.gov/dfe/pubs/flameret/ffr-alt.htm>
- (OSPAR, 2001): OSPAR Priority Substances Series; Certain Brominated Flame Retardants – Polybrominated Diphenylethers, Polybrominated Biphenyls, Hexabromocyclododecane, OSPAR Commission 2001 (2004 Update)
- (BMU, 2000): 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

Specific national and international risk management reports for Hexabromobiphenyl have not been available. However, there are a number of reports such as Danish EPA (1999), OSPAR (2001), BMU (2000), UBA (2003a, 2003b), USEPA (2005), which address the issue of control and substitution of brominated flame retardants at international or national scale.

General aspects of management for PBBs without further specification are reported in the Draft “Technical guidelines for the environmentally sound management of wastes consisting of, containing or contaminated with polychlorinated biphenyls (PCBs), polychlorinated terphenyls (PCTs) or polybrominated biphenyls (PBBs)”, Version 7 April 2006, available at <http://www.basel.int/techmatters/index.html>.

1.4 Status of the chemical under international conventions

Hexabromobiphenyl is listed in Annex I of the Protocol to the Convention on Long-range Transboundary Air Pollution (CLRTAP) on Persistent Organic Pollutants. The provisions of the Protocol oblige Parties to phase out all production and uses of Hexabromobiphenyl.

Hexabromobiphenyl, together with other PBBs, is also included in the UNEP/FAO Rotterdam Convention on the Prior Informed Consent Procedure (PIC) for Certain Hazardous Chemicals and Pesticides in International Trade.

Under the OSPAR Convention, brominated flame retardants (including hexabromobiphenyl) are enumerated as part of the List of Chemicals for Priority Action (March 2002). A background document has been prepared by Sweden. It was first published 2001 and was updated in 2004 (OSPAR, 2006). The action recommended in the updated document is to support several measures of the European Community on Polybrominated Biphenyls and to develop an OSPAR monitoring strategy for several Polybrominated Biphenyls and to review the need for further OSPAR measures to supplement the eventual measures of the European Community.

Under the HELCOM Convention² Hexabromobiphenyl is listed as a selected substance for immediate priority action (Recommendation 19/5, Attachment, Appendix 3) and is scheduled for elimination (Annex I, part 2). HELCOM aims to move towards the target of the cessation of discharges, emissions and losses of hazardous substances by the year 2020.

Under the Basel Convention, PBBs are classified as hazardous in Annex VIII without further specification.

The Strategic Approach to International Chemicals Management (SAICM) includes POPs as a class of chemicals. An objective of SAICM is to ensure by 2020 that chemicals or chemical uses that pose an unreasonable and otherwise unmanageable risk to human health and the environment (among other POPs) based on a science-based risk assessment and taking into account the costs and benefits as well as the availability of safer substitutes and their efficacy, are no longer produced or used for such uses (SAICM 2006).

1.5 Any national or regional control actions taken

In the European Union, Hexabromobiphenyl is listed in Annex I to Regulation (EC) No 850/2004 on persistent organic pollutants with complete prohibition of production and use in all the 27 Member States.

The EC Directive 2002/96/EC on Waste from Electric and Electronic Equipment (WEEE) requires that brominated flame retardants have to be removed from any separately collected WEEE prior to further treatment. EC Directive 2002/95/EC on Restrictions on Certain Hazardous Substances in Electric and Electronic Equipment (ROHS) stipulates in article 4 that electric and electronic articles may not contain polybrominated biphenyls from July 2006³.

The issue of Hexabromobiphenyl in waste is addressed at the European level in Regulation 850/2004/EC. As amended by regulation 1195/2006/EC POPs such as Hexabromobiphenyl in wastes have to be destroyed if concentration limits of 50 mg/kg are exceeded.

At the national level, legal control actions taken have been reported by Canada and the USA.

In Canada all Polybrominated Biphenyls appear on Schedule 1 (List of Toxic Substances) of CEPA 1999, and are subject to prohibitions on their use. In addition, Polybrominated Biphenyls appear on Schedule 3, Part 1 (Export Control List – Prohibited Substances) of CEPA 1999, effectively prohibiting their export, except for the purpose of destroying the substance.

In the USA, Hexabromobiphenyl is subject to a TSCA Significant New Use Rule which would require notification to EPA prior to re-initiating manufacture or import for any use (63 FR 45955, August 28, 1998; 40 CFR 721.1790).

² http://www.helcom.fi/environment2/hazsubs/action/en_GB/list

³ For use in article 5(1) a maximum concentration of 0.1% by weight in homogenous material of PBB shall be tolerated

2 Identification of possible control measures

Control measures already widely implemented are elimination of production, use, export, and import. US EPA refers to the subjection of Hexabromobiphenyl to the Toxic Substances Control Act (TSCA) and the Significant New Use Rule which would require notification to EPA prior to re-initiation of manufacture or import for any use (63 FR 45955, August 28, 1998; 40 CFR 721.1790). Mauritius refers to the Dangerous Chemicals Control Act 2004 (DCCA) which subjects to control by the Dangerous Chemicals Control Board (DCCB) all importations of chemicals.

Exposure to Hexabromobiphenyl may occur in connection with the use of products, in the recycling of plastics containing PBBs and after disposal to landfills so that in general releases from articles in use and releases from waste should be considered when discussing the need for measures. (OSPAR, 2001).

Measures related to stocks and articles in use, for release control and clean-up are not addressed in the responses to the Annex F questionnaire.

As Hexabromobiphenyl is an intentionally produced chemical, the most evident and efficient control measure would be the **prohibition of all production and uses** of Hexabromobiphenyl and Hexabromobiphenyl containing products and articles. Alternatively, in accordance with Article 3(1), legal and administrative measures (e.g. withdrawal or denial of pre-production and pre-marketing authorisation of chemicals) necessary to eliminate Hexabromobiphenyl would have the same impact. As no remaining uses of Hexabromobiphenyl have been identified, listing of Hexabromobiphenyl in Annex A without any specific exemptions could be the primary control measure under the Convention.

Listing of Hexabromobiphenyl in Annex A would also mean that the provisions of Article 3 on export and import and of Article 6 on identification and sound disposal of stockpiles and waste would apply.

2.1 Alternatives

The Hexabromobiphenyl Risk Profile describes three principal commercial products that contained Hexabromobiphenyl in the USA and Canada:

1. acrylonitrile-butadiene-styrene (ABS) thermoplastics used for business machine housings and electrical products such as radio and TV;
2. fire retardant in cable coatings and lacquers, and
3. fire retardant in polyurethane foam for auto upholstery.

Consequently evaluation and assessment of alternatives should focus on these uses as far as information is available.

A number of reports on risk assessment of alternative substances and processes are available. The OSPAR priority substances Series (OSPAR, 2001) provides summary information on alternatives for brominated flame retardants. The Danish Environmental Protection Agency has described alternative halogen-free flame retardants for a variety of uses including epoxy, phenolic resins, rigid and soft polyurethane foam, textiles, and a variety of plastics including ABS (Danish EPA, 1999). Both drop-in chemical substitutes and alternative materials are listed. US EPA has described process alternatives and chemical substitutes for polyurethane

foam (USEPA, 2005). The German Federal Ministry of Environment has reported on alternatives for flame retardants used in electronics, upholstery, and other sectors (BMU, 2000).

As brominated flame retardants only account for about 15% of the global flame retardant consumption, principally a large number of compounds may be considered as alternatives (OSPAR, 2001). Substitution can take place at three levels:

1. brominated flame retardants can in some applications be replaced by another flame retardant without changing the base polymer; (major group of substitutes)
2. the plastic material, i.e. the base polymer containing flame retardants and other additives, can be replaced by another plastic material; (e.g. polysulfone, polyaryletherketone and polyethersulfone)
3. a different product can replace the product, e.g. the plastic material is replaced by another material (e.g. wool), or the function can be fulfilled by the use of a totally different solution.

Reported chemical substitutes (see indent 1) currently used in Europe comprise the group of (a) organophosphorus compounds, (b) inorganic fire retardants and (c) nitrogen containing compounds (Danish EPA, 1999).

- (a) The group of organophosphorus contains the following main substances divided into the groups of:
 - 1) halogenated organophosphorus (Tris dichloropropyl phosphate, tris-chloropropyl-phosphate and tri-chloroethyl phosphate)
 - 2) non-halogenated organophosphorus (Triphenyl phosphate, Tricresyl phosphate, Resorcinol bis(diphenylphosphate), Phosphonic acid, (2-((hydroxymethyl)carbonyl)ethyl)- dimethyl ester, Phosphorus and nitrogen constituents for thermosets)
- (b) The group of inorganics contains Aluminium trihydroxide, Magnesium hydroxide, Ammonium polyphosphate, Red phosphorus and Zinc borate
- (c) The group of nitrogen containing compounds contains melamine and melamine derivatives, e.g. melamine cyanurate and melamine polyphosphate

In addition USEPA 2005 provides an assessment for Tribromoneopentyl alcohol, Chloroacetyl phosphate, other aryl phosphates, Tetrabromophthalate diol ester and reactive brominated flame retardants as potential substitutes for PeBDE.

Tetrabromobisphenyl (TBBP) and reactive phosphorus polyols have been mentioned as potential alternatives as well.

As an overall assessment the Danish report on alternative flame retardants (Danish EPA, 1999) makes the following assessment:

1. Substitutes are available for most applications at relatively low extra cost;
2. Organophosphorus compounds can be released from products in significant amounts;
3. Inorganic phosphorus compounds are more positive than organophosphorus ones though a more comprehensive assessment is needed;

4. Aluminum hydroxide has desirable minimal toxicity characteristics presumable shared by magnesium hydroxide though no assessment is currently available; however high loading may be a disadvantage
5. Zinc borate and melamine may be desirable but require a more comprehensive assessment

The German report on substitution of environmentally relevant flame retardants (BMU, 2000) takes the following conclusions:

- 1) More data is needed to assess non-halogen phosphoric esters;
- 2) Melamine is problematic (due to lack of data, presence in environmental samples and moderate organ toxicity); and
- 3) Merely zinc borate, magnesium hydroxide and expandable graphite should not cause any problems when used.

In addition the report concludes that the substitution of alternatives for POPs provokes a deeper question about methods to evaluate and compare the hazards of various substances.

The OSPAR report concludes that available data show that there are less hazardous alternatives for use a flame retardant e.g. aluminium trihydroxide. But it cannot be disregarded that less suitable substances might be among the alternatives. When industry selects a method to inhibit fire, data has to be generated in order to allow a good choice from an industrial/product and environmental point of view (OSPAR, 2001).

It has to be stated that under HELCOM⁴ Triphenyl phosphate and Tricresyl phosphate are listed as potential substances of concern (Recommendation 19/5, Attachment, Appendix 2). A comparable procedure has been taken for TBBP-A which is enumerated in the list of chemicals for priority action (March 2002) under OSPAR.

The assessment of potential alternatives in the environmental profiles of chemical flame retardant alternatives for low-density polyurethane foam (USEPA, 2005) reveals an overall hazard of investigated substances being moderate for human health and ranging from low to high for the aquatic environment. Melamine, Tris (1,3-dichloro-2-propyl) phosphate (TDCPP) and Ammonium Polyphosphate (APP) are shortly addressed but assessed as less appropriate for low density polyurethane foam in the US report due to technical aspects (scorching).

Reported alternative technologies (ident 3) comprise barrier technologies, graphite impregnated foam and surface treatment (USEPA, 2005).

One screening guide focuses on evaluating environmentally preferable flame retardants for TV enclosures by developing and using a “Green Screen” (Rossi et al., 2007) 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.

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.” (Lowell, 2005). The Framework discusses goals, guiding principles, decision

⁴ http://www.helcom.fi/Recommendations/en_GB/rec19_5

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.

In the light of parallel work on risk management evaluation of other brominated flame retardants under the Stockholm Convention and having in mind a certain convertibility of substances in a number of uses, consistency in recommendations for alternatives should be aimed at as far as appropriate.

2.1.1 Description of alternatives (substances)

According to OSPAR 2001, alternatives mentioned as chemical substitutes for electric and electronic equipment (e.g. aluminium trihydroxide, magnesium hydroxide, red phosphorus or organic phosphorus compounds) may not be viable for equipment which needs to meet certain demands with respect to technical and safety standards.

The flame retarded plastics used for switches, sockets and other applications where the material is in direct contact with live parts of electronic and electrical appliances are mainly made of thermoplastic polyester and polyamides. According to the Danish Environmental Protection Agency decaBDE has been substituted by Tetrabromobisphenol A (TBBP-A) and brominated styrene, but diarylphosphonate, melamine cyanurate or red phosphorus may be used as well.

Flame retardants for rigid polyurethane foams may be based on ammonium polyphosphates or red phosphorus. For flexible foams chlorinated phosphate esters, in some cases combined with melamine, ammonium polyphosphates and reactive phosphorus polyols are used.

Polysulfone, polyaryletherketone and polyethersulfone are plastics that are self-extinguishing and can be used without the addition of flame retardants. Less flammable materials e.g. wood and metals can also replace plastic material. Another example of the substitution of material is using wool instead of a more flammable fabric (OSPAR, 2001).

Alternatives for ABS plastics

Organic phosphorus compounds which are available as halogenated or non-halogenated substances can serve as alternatives for use in ABS plastics.

Halogenated organophosphorus compounds include tris-chloropropyl-phosphate (TCPP), tris-chloroethyl-phosphate, and tris dichloropropyl phosphate (TDCPP) (BMU, 2000). According to (USEPA, 2005) TDCPP is often used in polyurethane foam in the US and abroad. However, tris dichloropropyl phosphate, tris-chloropropyl-phosphate and tri-chloroethyl phosphate entail moderate concern for carcinogenicity, reproductive toxicity, developmental toxicity, systemic toxicity, genotoxicity, acute and chronic ecotoxicity, and persistence. (WHO, 1998), (USEPA, 2005)

Tetrabromobisphenol A (TBBPA or TBBP-A) is regarded as very poisonous to water-living organisms and very persistent. This flame retardant is mainly used in printed circuit boards. Since TBBPA is chemically bound to the resin of the printed circuit board, there is no exposure of the aquatic environment and therefore no risk.

Non-halogenated organic phosphorus compounds as alternative flame retardants for High Impact Polystyrene (HIPS) and poly carbonate (PC) plastics include commonly used substances such as triphenyl phosphate (TPP), tricresyl phosphate (TCP), resorcinol

bis(diphenylphosphate) (RDP), and phosphonic acid (2-((hydroxymethyl) carbamyl)ethyl)-dimethyl ester (Pyrovatex®) (Danish EPA, 1999).

(USEPA, 2005) reports moderate overall hazard for TPP while it is considered to be environmentally hazardous in Germany due to its toxicity to aquatic organisms (BMU, 2000) TCP toxicity apparently differs according to isomer. IPCS recommends the use of purified m- and p- isomers to prevent formation of the highly toxic o-isomer (Danish EPA, 1999). RDP is usually used in combination with TPP.

Pyrovatex® is not well-characterized though the Danish report notes that it is a weak inhibitor of acetyl choline esterase and the microsomal enzyme system and that high concentrations induced chromosome aberrations and reverse mutations. The German report notes that Pyrovatex easily separates formaldehyde and often is used together with ethylene carbamide to help trap released formaldehyde (BMU, 2000).

Both the German and Danish reports comment on the insufficiency of human and environmental toxicity data for RDP. Due to the absence of toxicity information and its possible transmission to humans from use of consumer products, the reports conclude that the data is insufficient to be able to make a recommendation.

Alternatives in coatings and lacquers

Halogen-free rubber cables can contain aluminium trihydroxide and zinc borate as flame retardant alternatives and incorporate the ethylene vinyl acetate polymer as well.

Aluminum trihydroxide is the most frequently used flame retardant (Danish EPA, 1999). Due to an endothermic reaction when decomposing and other properties it is highly effective and also suppresses smoke. Its functional disadvantage is that large amounts are required (up to 50%) which can affect the properties of the material. It would be extremely unlikely for its use in consumer products to cause adverse effects. Accumulation of the substance in food chains is not detectable (Danish EPA, 1999). Also the German alternatives report describes the use of aluminum trihydroxide as a flame retardant as “unproblematic.”

Magnesium hydroxide has comparable effects, however the environmental effects still have to be assessed (Danish EPA, 1999).

Zinc borate is often combined with aluminum trihydroxide and used to substitute for antimony trioxide. The German report describes the teratogenicity of boron along with its ability to irritate the eyes, respiratory organs, and skin at high levels. It assumes that its use as a flame retardant will not result in significant additional concentrations for humans. However, it concludes that it would be important to measure the ability for boron to be released in dust before its wide use in consumer products in homes.

Alternatives for polyurethane foams

Ammonium polyphosphate (APP) is an additive flame retardant currently used to flame retard flexible and rigid polyurethane foams, as well as intumescent laminations, molding resins, sealants and glues. APP formulations account for approximately 4-10% in flexible foam, and 20-45% in rigid foam (USEPA, 2005). APP is commonly used in combination with Aluminium hydroxide and Melamine. It metabolizes into ammonia and phosphate and is not thought to cause acute toxicity in humans (BMU, 2000). 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. Skin irritation is possible due to the formation of phosphoric acids.

Red phosphorus mainly used in polyamids is easily ignited and poorly characterized toxicologically. There is no data available for red phosphorus on ecotoxicity, carcinogenicity, mutagenicity, long-term toxicity, or toxicokinetics and no data exists on concentrations of red phosphorus in indoor or outdoor air (from sewage sludge) as a consequence of incorporating red phosphorus into products. Eye and mucous membrane irritation can result due to the formation of phosphoric acid. Ecosystem accumulation is thought to be unlikely (BMU, 2000). US government researchers have noted that high levels of toxic phosphine were observed during long-term storage of red phosphorus (Anthony et al., 2006).

Information in (Danish EPA, 1999) confirms the observations made, and states that “smaller producers of plastic products avoid the use of red phosphorus”.

Melamine and its derivatives (cyanurate, polyphosphate) are currently used in flexible polyurethane foams, intumescent coatings, polyamides and thermoplastic polyurethanes (Special Chemicals, 2004). They are used effectively in Europe in high-density flexible polyurethane foams but require 30 to 40 percent melamine per weight of the polyol.

Melamine and its derivatives display several toxic effects in animals. (USEPA, 1985, Danish EPA, 1999). In a fire, melamine cyanurate will release toxic fumes such as hydrocyanic acid and isocyanate (BMU, 2000).

However the Danish report notes that based on the results of the Swedish flame retardants project (Berglund, 1995) and a study from Stevens et al. (1999) there is no data on emission from products and that melamine appears to have low acute and chronic toxicity and concludes that, “...no adverse effects are envisaged from the level of exposure expected from the use of melamine as a flame retardant.”(Danish EPA, 1999).

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” (BMU, 2000).

According to IPEN specific reactive phosphorus polyols as potential alternative for soft polyurethane foam 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) (OPCW, 2006). 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.” (Munro et al., 1999) Other types of toxicity information are minimal but the substance reacts violently with water (USEPA, 1985). The phosphonic acid family also includes amino-methyl phosphonic acid (AMPA), a degradation product of the herbicide, glyphosate (also known as [carboxymethylamino] methyl phosphonic acid.) (Annex F responses, 2007, IPEN).

The US EPA Design for Environment report on flame retardant alternatives (USEPA, 2005) investigated the toxicological properties of 15 chemical substitutes for PentaBDE in low density foam. 12 of these substances have a moderate or high concern for persistence or would produce persistent degradation products. An additional 6 substances have a moderate concern for the ability to bioaccumulate. All substances (including triphenyl phosphate, tribromoneopentyl alcohol and proprietary aryl phosphates) raised moderate overall concern for human health and ranged from low to high hazard for the aquatic environment.

2.1.2 *Description of alternatives (technologies)*

Three currently-available alternative technologies (barrier technologies, graphite impregnated foam and surface treatment) are shortly discussed in US EPA 2005.

Barrier technologies have the widest immediate commercial applicability and involve layers of materials that provide fire resistance. These include boric acid-treated cotton materials used in mattresses; blends of natural and synthetic fibers used in furniture and mattresses (VISIL, Basofil, Polybenzimidazole, KEVLAR, NOMEX and fiberglass); and high performance synthetic materials used in firefighter uniforms and space suits. As regards barrier technologies that use cotton and boric acid potential negative effects of boron (see above; BMU 2000) should be taken into account and it would be important to measure the ability for boron to be released in dust before its wide use in consumer products in homes.

More information on barrier fabrics or even eliminate the use of filling material can be found in (Lowell, 2005) and in (Posner, 2004) (USEPA, 2005).

Graphite impregnated foam and surface treatments have limited commercial uses. Graphite impregnated foam (GIF) can be considered an “inherently flame-resistant foam” that is self-extinguishing and highly resistant to combustion. It is a relatively new technology and is largely used in niche markets such as for general aircraft seating.

Surface treatments are also used in some applications and niche markets and may be appropriate for some textile and furniture manufacturing. However, surface treatments may not be viable as industry-wide replacements for use in low-density foam (USEPA 2005):

2.1.3 *Technical feasibility*

All the alternatives described above are technically feasible and have been used in commercial applications (Annex F responses, 2007, IPEN). No specific comments on this topic have been provided by other parties.

2.1.4 *Costs, including environmental and health costs*

The prices of the alternatives are in general not higher than the BFRs but higher loading is often necessary. This is in particular true with respect to the inorganic compounds aluminum trihydroxide and magnesium hydroxide. Due to the low price of aluminum trihydroxide alternative materials may not be more expensive than BFR containing materials, but magnesium containing materials will usually be significantly more expensive. (Danish EPA, 1999)

As concerns alternative technologies (USEPA, 2005) describes the boric acid-treated cotton as “... the least expensive flame-retardant barrier materials available.” However, also GIF modified foams can be priced competitively by minimizing the expense associated with flame-retardant fabric.

According to IPEN however, there are important points to consider when evaluating the costs of alternatives for any product as specified in (Ackermann et al., 2006):

- Alternatives with a higher initial purchase cost may actually be more cost effective over the life of the product when durability and other factors are taken into account.
- Mass-production of alternatives can significantly lower their costs.
- The costs of initiatives to protect health and the environment are frequently overestimated in advance and later decline rapidly after the regulation is implemented.

2.1.5 Efficacy

According to IPEN the alternatives described above meet US federal and state regulatory requirements along with standards bodies such as ASTM (American Society for Testing and Materials) and UL (Underwriters Laboratories). However, chemical manufacturers and foam manufacturing trade groups do not consider APP to be an alternative for brominated flame retardants on a large scale. Reasons for this are that APP is typically incorporated as a solid, it has adverse effects on foam properties and processing and it is not considered to be as effective as a fire retardant compared to other alternatives (USEPA, 2002 quoted in USEPA 2005).

Melamine and TDCPP as two of the most commonly used chemicals to flame retard high-density, flexible polyurethane foam either result in scorching of the foam (an aesthetic effect unless severe) or a negative effect on the physical properties of foam if used in low-density flexible foams. Also, many formulations of these chemicals are available only as solids; making them less desirable as drop in substitutes for some brominated flame retardants (USEPA, 2005).

2.1.6 Availability

The alternatives described here are available since many are already in commercial use (Annex F responses, 2007, IPEN).

2.1.7 Accessibility

The alternatives described here are accessible since many are already in commercial use (Annex F responses, 2007, IPEN).

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

2.2.1 Technical feasibility

The essential phase-out of global production and use of Hexabromobiphenyl indicates that technically feasible alternatives have already been implemented (Annex F responses, 2007, IPEN).

2.2.2 Costs, including environmental and health costs

According to IPEN the considerable phase-out of Hexabromobiphenyl that has already occurred indicates that costs of alternatives have not inhibited their substitution. However, IPEN notes that there are inherent problems with using cost-benefit analysis to evaluate risk reduction and regulatory decisions. A fundamental problem is the difficulty of estimating the benefits attributed to a particular control measure. As stated in (Heinzerling et al., 2004) there is no meaningful way of assigning a dollar figure to human and environmental health (Annex F responses, 2007, IPEN).

No specific comments on this topic have been provided by other parties. As the phase out of Hexabromobiphenyl however, has taken place long ago already, significant costs from a global ban of the product would not be expected. Additional costs could arise from specific provisions concerning identification, collection, dismantling and disposal of remaining equipment.

According to IPEN any consideration of costs associated with the phase-out of Hexabromobiphenyl and proper management of its wastes must fully take into account the Polluter Pays Principle.⁵ Even after production of Hexabromobiphenyl ceases, it remains necessary for governments to ensure that wastes are managed and disposed in appropriate ways that do not significantly harm public health and the environment.

This too frequently results in external costs that society must bear unless appropriate economic instruments exist to properly internalize these costs within the importer/producer/user industry. Governments are entitled to take measures that result in the polluter bearing the administrative costs to governments of preventing and controlling pollution from Hexabromobiphenyl and including emissions from wastes.⁶

Mechanisms are needed to enable governments to recover from PBB-producing industries the costs that they and society incur associated with protective control measures that take effect when Hexabromobiphenyl is listed by the Stockholm Convention as a POP.

The European Union Risk Reduction Strategy for octaBDE contains an analysis of advantages and drawbacks of possible measures to reduce the risks from octa-BDE (RPA, 2002).

⁵ Rio Declaration on Environment and Development, Principle 16, adopted by the 1992 United Nations Conference on Environment and Development. <http://www.unep.org/Documents/Default.asp?DocumentID=78&ArticleID=1163>

⁶ OECD Joint Working Party on Trade and Environment, The polluter pays principle as it relates to international trade, (2002) [http://www.oelis.oecd.org/olis/2001doc.nsf/43bb6130e5e86e5fc12569fa005d004c/988d25625e791068c1256c98003a2fcb/\\$FILE/JT00137174.PDF](http://www.oelis.oecd.org/olis/2001doc.nsf/43bb6130e5e86e5fc12569fa005d004c/988d25625e791068c1256c98003a2fcb/$FILE/JT00137174.PDF)

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

2.3.1 Health, including public, environmental and occupational health

According to the German Federal Environment Agency impacts of a restriction/ban of Hexabromobiphenyl under the Stockholm Convention are expected to be rather low for the European region as Hexabromobiphenyl is already restricted for certain uses within the EU and as a critical level for water has lately been defined. On a global scale however, a positive impact on human health and on the environment can be expected from a ban of Hexabromobiphenyl (Annex F responses, 2007, Germany). Also the Czech Republic does not expect impacts of possible control measures (Annex F responses, 2007, Czech Republic).

According to IPEN elimination of Hexabromobiphenyl production, use, export, and import through a listing in Annex A of the Stockholm Convention would positively impact human health and the environment by preventing use of a persistent toxic substance. No discernible negative impacts on society have been reported from prohibition or phase-out of Hexabromobiphenyl as it is apparently not currently in use. A listing in Annex A would prevent future production and integration into products.

2.3.2 Agriculture, including aquaculture and forestry

There are no likely economic impacts on agriculture, as Hexabromobiphenyl has not been used in that sector. The positive environmental impacts in the form of reduced pollution could also have indirect positive impact on agriculture.

2.3.3 Biota (biodiversity)

As the persistent, bioaccumulative and toxic properties of Hexabromobiphenyl were shown under the POPs-Protocol and under the Stockholm Convention, a positive impact on biota from a ban/restriction of the substance can be expected according to the German Federal Environment Agency.

2.3.4 Economic aspects

According to IPEN cost competitive alternatives that do not exhibit POPs characteristics have already been implemented by companies for all uses of Hexabromobiphenyl.

2.3.5 Movement towards sustainable development

As the persistent, bioaccumulative and toxic properties of Hexabromobiphenyl as well as its potential for a long-range transboundary transport were shown under the POPs-Protocol and as by the POP RC of the Stockholm Convention which concluded that HBB meet the screening criteria listed in Annex D, a positive impact on a globally sustainable development from a ban/restriction of the substance is to be expected by the German Federal Environmental Agency (Annex F responses, 2007, Germany).

According to IPEN reduction and elimination of Hexabromobiphenyl is consistent with sustainable development plans that seek to reduce emissions of toxic chemicals. A relevant global plan is the Strategic Approach to International Chemicals Management (SAICM) that emerged from the World Summit on Sustainable Development⁷. The Global Plan of Action of SAICM contains specific measures to support risk reduction that include prioritizing safe and effective alternatives for persistent, bioaccumulative, and toxic substances.

2.3.6 *Social costs*

Since Hexabromobiphenyl has already been replaced with other substances or technologies, the impact on costs for consumers of an Annex A listing should be negligible according to IPEN.

2.3.7 *Other impacts (Waste and disposal implications- stocks, contaminated sites)*

Since Hexabromobiphenyl has already been largely phased-out, the impact on municipal waste and disposal according to IPEN should be minimal.

However, the Risk Profile outlines former consumer uses of Hexabromobiphenyl including ABS plastic used for business machine housings and electrical products such as radio and TV, cable coatings, and polyurethane foam.

In addition there are concerns over export of electronic waste to developing countries leading to Hexabromobiphenyl releases during recycling operations. Finally, burning or incineration of Hexabromobiphenyl-containing waste could lead to formation and release of brominated dibenzo-p-dioxins and -furans.

A listing of Hexabromobiphenyl in Annex A would subject wastes, products or articles containing the substance to Article 6 of the Stockholm Convention and require that they are disposed of in environmentally sound manner.

According to the US EPA approximately 11.8 million pounds (5.4 million kg) of Hexabromobiphenyl were used in commercial and consumer products in the U.S. with an estimated use life of 5-10 years. It is assumed that most of these products, such as TV cabinet and business machine housings must have been disposed of by land filling or incineration (US ATSDR, 2004). The sole U.S. producer depleted their remaining stocks in April 1975 (IARC Monographs, 1972 to present, V. 18, p. 110, quoted in TOXNET entry, <http://toxnet.nlm.nih.gov>)

There are no data on obsolete products and stocks in Zambia.

⁷ <http://www.chem.unep.ch/saicm/>

2.4 Other considerations

2.4.1 Access to information and public education

As Hexabromobiphenyl is prohibited within the EU and as a critical level for water has been defined, the need for public education programmes on the impacts of Hexabromobiphenyl is low in Germany. However, information can be obtained by everybody from the official websites of the Stockholm Convention and CLRTAP POPs-Protocol as well as from websites and helpdesks of national authorities dealing with chemicals (Annex F responses, 2007, Germany).

In the Czech Republic the issue of Hexabromobiphenyl is part of the SC/UN ECE CLRTAP education and awareness campaign under the national implementation plan. In Zambia access to environmental information is low, though it has increased in the recent past (ECZ 2001, State of the environment, Lusaka, Zambia).

2.4.2 Status of control and monitoring capacity

According to IPEN listing Hexabromobiphenyl in Annex A will involve control measures that are straightforward to communicate and therefore should be effective and suitable, even in countries that have limited chemical regulatory infrastructure.

3 Synthesis of information

According to the Risk Profile on Hexabromobiphenyl known commercial production (about 5,400 t) has mainly taken place in the USA from 1970 to 1975 by a sole producer Michigan Chemical Cooperation, St. Louis. In other regions of the world known production was restricted to octa- and decabromodiphenyl ethers which were regarded to be less toxic.

There is no information on potential Hexabromobiphenyl production in Russia, developing countries or countries with economies in transition. According to Danish EPA (1999), PBBs may still be in production in Asia.

Hexabromobiphenyl has mainly been used in ABS plastics and coated cables. Based on an expected lifetime of 5-10 years for electrical and electronic products it is expected that all of the products have already been disposed of (US ATSDR, 2004).

Hexabromobiphenyl is already listed in Annex I of the Protocol to the Convention on Long-range Transboundary Air Pollution (CLRTAP) on Persistent Organic Pollutants (Aarhus Protocol), requiring to phase out all production and uses. Hexabromobiphenyl, together with other PBBs, is also included in the UNEP/FAO Rotterdam Convention on the Prior Informed Consent Procedure (PIC) for Certain Hazardous Chemicals and Pesticides in International Trade. OSPAR lists Hexabromobiphenyl as chemicals of priority action since 1998.

At the European level Hexabromobiphenyl is listed in Annex I to Regulation (EC) No 850/2004 on persistent organic pollutants with complete prohibition of production and use. In addition Directive 2002/96/EC on Waste from Electric and Electronic Equipment (WEEE) requires that brominated flame retardants have to be removed from any separately collected WEEE prior to further treatment. EC Directive 2002/95/EC on Restrictions on Certain Hazardous Substances in Electric and Electronic Equipment (ROHS) stipulates in article 4 that electric and electronic articles may not contain polybrominated biphenyls from July 2006⁸.

The issue of Hexabromobiphenyl in waste is addressed at the European level in Regulation 850/2004/EC. As amended by regulation 1195/2006/EC Hexabromobiphenyl in wastes has to be destroyed if concentration limits of 50 mg/kg are exceeded.

At the national level legal control actions taken have been reported by Germany, Canada and the USA. In Canada, Polybrominated Biphenyls appear on Schedule 1 (List of Toxic Substances) of CEPA 1999, and are subject to prohibitions on their use. In addition Polybrominated Biphenyls appear on Schedule 3, Part 1 (Export Control List – Prohibited Substances) of CEPA 1999, effectively prohibiting their export, except for the purpose of destroying the substance. In the USA Hexabromobiphenyl is subject to a TSCA Significant New Use Rule which would require notification to EPA prior to re-initiation of manufacture or import for any use.

Concerning chemical substitutes and technical alternatives reported data (although not specifically related to Hexabromobiphenyl but as overall alternatives to brominated flame retardants show that there are less hazardous alternatives e.g. aluminium trihydroxide. However, it cannot be disregarded that more harmful substances might be among the alternatives compared to the group of brominated flame retardants as such (e.g. halogenated

⁸ For use in article 5(1) a maximum concentration of 0.1% by weight in homogenous material of PBB shall be tolerated

phosphorus and partially non-halogenated phosphorus compounds). Providing guidance on criteria for selecting alternatives to Hexabromobiphenyl should be part of the risk management strategy for Hexabromobiphenyl elimination. This would help discourage substitution of Hexabromobiphenyl with other harmful substances. Criteria should include a non-hazardous synthetic pathway; minimum human and environmental toxicity; minimum release during product use; minimum formation of hazardous substances during incineration or burning; and the ability to be recycled or degrade into a non-hazardous substance.⁹

As production of Hexabromobiphenyl has ceased some decades ago, availability of alternatives, efficacy and cost implications do not constitute a problem. Based on the same background significant negative impacts of listing of Hexabromobiphenyl in Annex A on society are not expected.

The Persistent Organic Pollutants Review Committee, has decided, in accordance with paragraph 7 (a) of Article 8 of the Convention, given the fact that Hexabromobiphenyl is likely, as a result of its long-range environmental transport, to lead to significant adverse human health and environmental effects such that global action is warranted.

A beneficial effect could be expected in case of currently unknown production in any part of the world, if management and disposal of potentially remaining stocks (e.g. coated cables, equipment exceeding average life time) would be further regulated and reintroduction of Hexabromobiphenyl would be prevented on a global scale.

Having evaluated the risk profile corresponding to Hexabromobiphenyl, and having prepared its risk management evaluation, the Committee concludes that this chemical is likely, as a result of long-range environmental transport, to lead to significant adverse effects on human health and/or the environment, such that global action is warranted. Although Hexabromobiphenyl is not known to be produced and used anymore, it is important to prevent re-introduction of this substance.

Therefore, in accordance with paragraph 9 of Article 8 of the Convention, the Committee recommends the Conference of the Parties to the Stockholm Convention to consider listing and specifying the related control measures of Hexabromobiphenyl in Annex A. As no remaining production or uses of Hexabromobiphenyl have been identified, listing of Hexabromobiphenyl in Annex A without any specific exemptions is possible.

⁹ Danish Environmental Protection Agency, Brominated flame retardants: Substance flow analysis and assessment of alternatives, June 1999

References

(Ackermann et al., 2006)

Ackerman F, Massey R. The Economics of Phasing Out PVC, Global Development and Environment Institute, Tufts University, USA, May 2006. Available at http://www.ase.tufts.edu/gdae/Pubs/rp/Economics_of_PVC_revised.pdf

(Annex F responses, 2007)

Responses to request for information on Annex F requirements for the proposed POPs substances which have been submitted in 2007 to the Persistent Organic Pollutants Review Committee (POPRC) under the Stockholm Convention. Available at <http://www.pops.int/documents/meetings/poprc/prepdocs/annexFsubmissions/submissions.htm>, accessed April 2007

(Anthony et al., 2006)

Anthony JS, Davis EA, Haley MV, McCaskey DA, Kristovich RL. Edgewood Chemical Biological Center, Aberdeen Proving Ground, MD. Chemical Characterization of the Pyrotechnically Disseminated KM03 Red Phosphorus Floating Smoke Pot. Govt Reports Announcements & Index (GRA&I), Issue 24, 2006

(Berglind, 1995)

Berglind, R. 1995. Human health hazard assessments of some flame retardants. PM 5/95. Swedish National Chemical Inspectorate, Stockholm.

(BMU, 2000)

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

(Danish EPA, 1999)

Danish Environmental Protection Agency, Brominated flame retardants: Substance flow analysis and assessment of alternatives, June 1999. Available at www.mst.dk/udgiv/Publications/1999/87-7909-416-3/html/default_eng.htm

(Heinzerling et al., 2004)

Heinzerling L, Ackerman. Priceless: Human Health, the Environment and Limits of the Market. The New Press, 288 pages, 2004

(IARC, 1978)

International Agency for Research on Cancer (IARC) - Summaries & Evaluations, Polybrominated Biphenyls, Vol.: 18 (1978) (p. 107)

(IPCS, 1994)

Environmental Health Criteria 152: Polybrominated biphenyls. IPCS International Programme on Chemical Safety. United Nations Environment Programme. International Labour Organisation. World Health Organization. Geneva 1994. Available at <http://www.inchem.org/documents/ehc/ehc/ehc152.htm>.

(IPCS, 1997)

Environmental Health Criteria 192: Flame Retardants: A General Introduction. IPCS International Programme on Chemical Safety. United Nations Environment Programme. International Labour Organisation. World Health Organization. Geneva 1997. Available at <http://www.inchem.org/documents/ehc/ehc/ehc192.htm>.

(Lowell, 2005)

Lowell Center for Sustainable Production, Prepared by Pure Strategies, University of Massachusetts Lowell, Lowell MA 01854, Decabromodiphenylether: An investigation of non-halogen substitutes in electronic enclosure and textile applications. April 2005

<http://sustainableproduction.org/downloads/DecaBDESubstitutesFinal4-15-05.pdf>

(Matthews et al., 1993)

Matthews HB, Eustic SL, Haseman J. National Institute of Environmental Health Science, Research Triangle Park, North Carolina 27709. Toxicity and carcinogenicity of chronic exposure to tris(2-chloroethyl)phosphate. *Fundam Appl Toxicol.* 1993 May; 20(4): 477-85

(Munro et al., 1999)

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

(National Toxicology Program, 1991)

National Toxicology Program, Tris(2-chloroethyl) phosphate Robert Chapin project officer, Dushyant Gulati and Leta Barnes, Environmental Health Research and Testing July 1991.

Available at <http://www.ehponline.org/members/1997/Suppl-1/dfa968.html>

(OPCW, 2006)

OPCW Declarations Branch, Some Scheduled Chemicals, 2006. Available at

<http://www.opcw.org/docs/publications/some%20scheduled%20chemicals.pdf>

(OSHA, 1999)

US Occupational Safety and Health Administration, Chemical Sampling Information, 19 January 1999. Available at http://www.osha.gov/dts/chemicalsampling/data/CH_274400.html

(OSPAR, 2001)

OSPAR Priority Substances Series; Certain Brominated Flame Retardants – Polybrominated Diphenylethers, Polybrominated Biphenyls, Hexabromo-Cyclododecane, OSPAR Commission 2001 (2004 Update)

(OSPAR, 2006)

OSPAR List of Chemicals for Priority Action (Update 2006), Reference number 2004-12, OSPAR commission

(Posner, 2004)

Posner. Survey and Technical Assessment of Alternatives to Decabromodiphenyl Ether (decaBDE) in Textile Applications, Swedish Chemicals Inspectorate KEMI 1/05 June 2005, available at http://www.kemi.se/upload/Trycksaker/Pdf/Rapporter/Rapport1_05.pdf

(Rossi et al., 2006)

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

(Rossi et al., 2007)

Rossi M, Heine L. Clean Production Action, Green Blue, The Green Screen for Safer

Chemicals –Version1.0: Evaluating environmentally preferable flame retardants for TV enclosures, 2007 <http://www.cleanproduction.org/library/Green%20Screen%20Report.pdf>

(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. available at:

http://www.defra.gov.uk/environment/chemicals/pdf/octa_bdpe_rrs.pdf

SAICM 2006

Strategic Approach to International Chemicals Management Comprising the Dubai Declaration on International Chemicals Management, the Overarching Policy Strategy and the Global Plan of Action (Issued by the secretariat for the Strategic Approach to International Chemicals Management, 6 June 2006, pending formal publication)

http://www.chem.unep.ch/saicm/SAICM%20texts/standalone_txt.pdf

(Stevens et al., 1999)

Stevens, G.C. & A.H. Mann. 1999. Risks and benefits in the use of flame retardants in consumer products. Polymer Reserch Centre, Uni. of Surrey for the UK Department of Trade and Industry. University of Surrey, Guildford.

(UBA, 2003a)

Guideline for use of environmentally sound substances for producers and industrial users of chemical products with water relevance. Part 5, Guidance for substitution of dangerous substances

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

(UBA, 2003b)

Guideline for use of environmentally sound substances for producers and industrial users of chemical products with water relevance. Part 3, Product specific strategy, additives in plastics
Leitfaden zur Anwendung umweltverträglicher Stoffe für die Hersteller und gewerblichen Anwender gewässerrelevanter Chemischer Produkte, TEIL 3, Produktspezifische Strategie, Additive in Kunststoffen, Umweltbundesamt, Februar 2003

(UNEP, 2006)

United Nations Environment Programme (2006), UNEP/POPS/POPRC.2/9, Draft risk profile: hexabromobiphenyl, Persistent Organic Pollutants Review Committee, Second meeting, Geneva, 6-10 November 2006

(US ATSDR, 2004)

Toxicological Profile for Polybrominated Biphenyls and Polybrominated Diphenyl Ethers (PBBs and PBDEs). US ATSDR, 2004. <http://www.atsdr.cdc.gov/toxprofiles/tp68.html>

(USEPA, 1985)

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>

(USEPA, 2005)

Environmental Profiles of Chemical Flame-Retardant Alternatives for Low-Density Polyurethane Foam, 2005. Available at <http://www.epa.gov/dfe/pubs/flameret/ffr-alt.htm>

(WHO, 1990)

WHO, Environmental Health Criteria 110; Tricresyl phosphate 1990. Available at <http://www.inchem.org/documents/ehc/ehc/ehc110.htm>

(WHO, 1998)

11 WHO Environmental Health Criteria 209: Flame retardants: tris(chloropropyl) phosphate and tris(2-chloroethyl) phosphate, 1998. Available at http://www.who.int/ipcs/publications/ehc/who_ehc_209.pdf

DRAFT