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

Addendum

Risk management evaluation on hexabromobiphenyl

At its third meeting, the Persistent Organic Pollutants Review Committee adopted the risk management evaluation on hexabromobiphenyl, on the basis of the draft contained in document UNEP/POPS/POPRC.3/11. The text of the risk management evaluation, as amended, is set out below. It has not been formally edited.

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HEXABROMOBIPHENYL

RISK MANAGEMENT EVALUATION

Adopted by the Persistent Organic Pollutants Review Committee
at its third meeting

November 2007

TABLE OF CONTENTS

Executive summary

The European Community and its Member States being Parties to the Stockholm Convention proposed Hexabromobiphenyl to be listed in Annex A of the Convention in 2005. At its 2nd meeting, the POP Review Committee 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.

Hexabromobiphenyl is an intentionally produced chemical that has been used as a flame retardant. According to the available information, the production and use of the substance has been ceased already years ago but it cannot be excluded that it is still in production or in use in some developing countries. Hexabromobiphenyl has mainly been used in ABS plastics and coated cables. Based on an expected lifetime of 5-10 years for electrical and electronical products it is expected that all of the products have already been disposed of.

The most efficient control measure would be the prohibition of all production and uses of Hexabromobiphenyl and hexabromobiphenyl containing products and articles. 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.

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 equally or more harmful substances might be among the alternatives compared to the group of brominated flame retardants as such (e.g. halogenated phosphorus and partially non-halogenated phosphorus compounds).

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. 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 would be further regulated and reintroduction of Hexabromobiphenyl would be prevented on a global scale.

1. Introduction

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

1.1. Chemical identity, production and uses

1.1.1. Chemical identity

Hexabromobiphenyl (HBB) 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 UNEP/POPS/POPRC.2/9 Annex B.

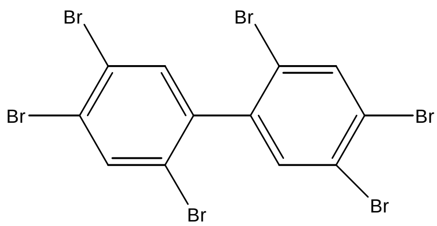
CAS chemical name:	hexabromo-1,1´-biphenyl
Synonyms:	hexabromobiphenyl;
	Biphenyl, hexabromo;
	1,1´- biphenyl, hexabromo -;
	HBB
Trade names:	FireMaster(R) BP-6;
	FireMaster(R) FF-1

Technical grade PBBs (FireMaster$^{(R)}$) contain several PBB compounds, isomers and congeners, HBB 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:	36355-01-8[1] (Common CAS number for HBB 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 0-1 (Structural formula source: EHC 192 (IPCS, 1997))

Figure 0-1: Structural formula of 2,2',4,4',5,5' hexabromobiphenyl



1.1.2. Production and uses

The following is a summary of the data on production and uses of HBB given in the risk profile. The commercial production of PBBs began in 1970. Approximately 6 million kg of PBBs were produced in the United States from 1970 to 1976. HBB constituted about 5.4 million kg (ca 88%) of this total. The production in the USA stopped in 1975. Re-initiation of manufacture of PBBs would require 90 days advance notification to EPA, during which time EPA would evaluate the intended use and associated activities, and could regulate the substance to prohibit or limit activities, if appropriate.

[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.

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

In the United States and Canada, HBB 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.

Approximately 5 million tonnes of HBB were produced in the USA from 1970 to 1976. Of the estimated 2,200 tonnes HBB produced in 1974, 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 HBB (one of these in 1972) because PBBs did not decompose in the ultimate incineration of scrapped automobiles.

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

The Committee developed a risk profile in accordance with Annex E at its second meeting in Geneva 6-10 November 2006. Based on the risk profile, it has concluded (Decision POPRC-2/3) that, in accordance with paragraph 7 (a) of Article 8 of the Convention, HBB 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 HBB to refine the risk profile further by providing estimations of the risks to human health and the environment from exposure to HBB, which should include the potential risk associated with the presence of HBB 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 HBB 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 the information specified in Annex F for HBB and further information to allow refinement of the hazard assessment and the risk profile of HBB.

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):

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, Hexabromo-Cyclododecane, 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 HBB 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

HBB 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 HBB.

HBB, 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 for the protection of the marine environment of the North-East Atlantic, brominated flame retardants (including HBB) 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 Helsinki Convention on the Protection of the Marine Environment of the Baltic Sea Area (HELCOM[2]) HBB 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.

Even if not being an international convention, the Strategic Approach to International Chemicals Management (SAICM) appears to be a noteworthy international action. SAICM was developed by a multi-stakeholder and multi-sectoral preparatory committee and supports the achievement of the goal agreed at the 2002 Johannesburg World Summit on Sustainable Development. SAICM does not specifically address HBB but includes POPs as a class of chemicals that might be prioritized for assessment and related studies. 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 others POPs) based on a scientific 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).

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[2] Helsinki Commission - Baltic Marine Environment Protection Commission http://www.helcom.fi/environment2/hazsubs/action/en_GB/list governing body of the Convention

1.5. Any national or regional control actions taken

In the European Union, HBB 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 2006[3].

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

The use of PBBs in textiles has been prohibited in the European Union already decades ago by means of Directive 1976/769/EEC.

At the national level, legal control actions taken have been reported by Canada, the USA and Australia. In Canada Polybrominated Biphenyls that have the molecular formula $C_{12}H_{(10-n)}Br_n$, in which “n” is greater than 2, appear on Schedule 1 (List of Toxic Substances) of CEPA 1999, and are subject to prohibitions on their manufacture, use, sale, offer for sale and import. In addition, these substances appear on Schedule 3, Part 1 (Export Control List – Prohibited Substances) of CEPA 1999, effectively prohibiting their export, except for the purpose of their destruction.

In the USA, HBB 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).

In Australia the introduction (i.e. manufacture or import) or export of HBB, octabromobiphenyl and decabromobiphenyl are prohibited under the Industrial Chemicals (Notification and Assessment) Regulations 1990 unless the Director of the National Industrial Chemicals Notification and Assessment Scheme (NICNAS) has given written permission.

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 HBB 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 HBB 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 taken into account when considering control 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 HBB is an intentionally produced chemical, the most efficient[4] control measure would be the prohibition of all production and uses of HBB and HBB 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 HBB would have the same impact. As no remaining uses of HBB have been identified, listing of HBB in Annex A without any specific exemptions could be the primary control measure under the Convention.

Listing of HBB 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.

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

[4] minimised effort to achieve specific objectives (here: no current and future production and use of Hexabromobiphenyl in order to avoid environmental releases and significant adverse effects on human health and/or the environment)

2.1. Alternatives

The HBB risk profile describes three principal commercial products that contained HBB 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.

Production and use of HBB has ceased in the USA, Canada, and probably most parts of the world. However, it is possible that HBB is still being produced and used in some developing countries or in countries with economies in transition. As most production and use has ceased, there are numerous alternatives available and in use. Since there may be some production and use still occurring, evaluation and assessment of alternatives is presented and will focus on the earlier known 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 compounds 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, resorcinal bis(diphenylphosphate), phosphonic acid, (2-((hydroxymethyl)carbamyl)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, chloroalkyl phosphate, other aryl phosphates, tetrabromophthalate diol diester and reactive brominated flame retardants as potential substitutes for PeBDE. Tetrabromobisphenol-A (TBBPA) and reactive phosphorus polyols have been mentioned as potential alternatives as well.

2.1.1. Description of alternatives (substances)

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, TDCPP, TCPP 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 direct exposure of the aquatic environment and therefore minimal risk to aquatic organisms. For disposal and recovery purposes circuit boards however, would be classified as hazardous under the Basel Convention if containing polybrominated biphenyls to an extend, that they possess Annex III characteristics (Annex VIII, A 1180). Consequently the European Regulation No (EC) 1013/2006 on Shipment of waste would subject such wastes to export prohibition in Article 36. TBBPA and other flame retardants are released during recycling of waste electrical and electronic equipment.[5]

Non-halogenated organic phosphorus compounds as alternative flame retardants for High Impact Polystyrene (HIPS) and polycarbonate (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, moulding 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,

[5] Morf LS, Tremp J, Gloor R. Huber Y, Stengele M, Zennegg M. Brominated flame retardants in waste electrical and electronic equipment: substance flows in a recycling plant. Environ Sci Technol 39:8691-8699, 2005

mutagenicity, or carcinogenicity. APP 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 from the 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 derivates 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 (Berglind, 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).

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 (DfE) 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 the US EPA DfE report (USEPA 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 fibres used in furniture and mattresses (VISIL, Basofil, Polybenzimidazole, KEVLAR, NOMEX and fibreglass); and high performance synthetic materials used in fire-fighter 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 none of the alternatives usually applied in the earlier known use fields of HBB are prohibited by federal or state laws for the uses described above and in this sense, they meet regulatory requirements meet US federal and state regulatory requirements. 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). (for risk assessment of alternative use see section 2.1.1)

2.1.6. Availability

The alternatives described here are available since many are already in commercial use (Annex F responses, 2007, IPEN). However, the fact that many alternatives are in commercial use does not necessarily mean they are available globally.

2.1.7. Accessibility

The alternatives described here are accessible since many are already in commercial use (Annex F responses, 2007, IPEN). However, the fact that many alternatives are in commercial use does not necessarily mean they are available globally.

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 HBB 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 HBB that has already occurred indicates that costs of alternatives have not inhibited their substitution.

No specific comments on this topic have been provided by other parties. As the phase out of HBB 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.

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 HBB under the Stockholm Convention are expected to be rather low for the European region as HBB 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 HBB (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 HBB 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 HBB 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 HBB 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 HBB 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 HBB.

2.3.5. Movement towards sustainable development

As the persistent, bioaccumulative and toxic properties of HBB as well as its potential for a long-range transboundary transport were shown under the POPs-Protocol and by the POPRC 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 expected by the German Federal Environmental Agency (Annex F responses, 2007, Germany). According to IPEN reduction and elimination of HBB 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 Development[6]. 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 HBB 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 HBB 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 HBB 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 HBB releases during recycling operations. Finally, burning or incineration of HBB-containing waste could lead to formation and release of brominated dibenzo-p-dioxins and -furans.

A listing of HBB 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 HBB 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

[6] http://www.chem.unep.ch/saicm/

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.

Against this background it can be assumed that there are hardly any products in service containing HBB because they are virtually all disposed of. Other impacts e.g. concerning stocks, waste and disposal or contaminated sites are therefore not expected.

2.4. Other considerations

2.4.1. Access to information and public education

As HBB 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 HBB is low in Germany. However, information can be obtained by everybody from the official websites of the Stockholm Convention and Convention on Long-range Transboundary Air Pollution (CLRTAP) Aarhus Protocol (on the control of POPs) 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 hexabromobipenyl is part of the SC/UN ECE CRLTAP 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 HBB 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. Concerning the waste control measures, it is in practice difficult to identify HBB containing articles and waste but based on the assumption that most products containing HBB have already been disposed of, it can be expected that no further control and monitoring capacity is required.

3. Synthesis of information

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

HBB 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).

HBB 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. HBB, 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 HBB as chemicals of priority action since 1998.

At the European level HBB 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 2006[7].

The issue of hexabromobiphenyl in waste is addressed at the European level in Regulation 850/2004/EC. As amended by regulation 1195/2006/EC HBB 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, Australia and the USA.

Concerning chemical substitutes and technical alternatives reported data (although not specifically related to HBB 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 equally or more harmful substances might be among the alternatives compared to the group of brominated flame retardants as such (e.g. halogenated phosphorus and partially

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

non-halogenated phosphorus compounds). Providing guidance on criteria for selecting alternatives to HBB should be part of the risk management strategy for HBB elimination. This would help discourage substitution of HBB 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.[8]

As production of HBB 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 HBB 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 HBB 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 HBB would be prevented on a global scale.

4. Concluding statement

Having evaluated the risk profile corresponding to HBB, having assessed and concluded on the rationale for a class approach on all hexabrominated biphenyls as laid down in the annex to this document, 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 HBB is not known to be produced or used anymore, it is important to prevent future production and use 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 of HBB in Annex A. As no remaining production or uses of HBB have been identified, listing of HBB in Annex A without any specific exemptions is feasible. Furthermore, the Committee recommends focusing the implementation efforts in identifying and managing articles and wastes containing HBB and setting the proper measures for avoiding that HBB is reintroduced in the future.

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

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Annex

Additional rationale for the “class approach” for groups of closely-related chemicals for all hexabromo biphenyls (42 congeners)

The available information on hexabromobiphenyl includes laboratory studies conducted either with mixtures or specific congeners and monitoring data for different combinations of congeners. In addition to the information summarized in the risk profile on hexabromobiphenyl, the scientific literature offers a significant number of reviews presenting the overall toxicity of this chemical family.

It is clear that the current level of information does not cover all hexabromobiphenyl congeners. Nevertheless, the information seems to be consistent with the generic assessment. Therefore, although differences in the properties that define persistent organic pollutant characteristics and their associated risk are expected among the congeners within this family, it is not likely that these differences would be so significant that they should preclude a generic assessment. The Convention already contains lists of closly related chemicals, the polychlorinated biphenyls (PCBs), toxaphene, polychlorinated dibenzo-p-dioxins and dibenzofurans.

In the light of the foregoing, the Committee supports the approach for listing hexabromobiphenyl as a group including all the hexabrominated congeners as originally proposed by the European Community and its member States.

It should be noted that the drafting group is making the present proposal after reviewing the characteristics of this particular group of chemicals and that it should not be generically extrapolated to other chemical families in which large differences among the properties of closely related homologues, congeners and isomers have been found.