DATA ON MANUFACTURE, IMPORT, EXPORT, USES AND RELEASES OF HBCDD AS WELL AS INFORMATION ON POTENTIAL ALTERNATIVES TO ITS USE

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Executive Summary

Information sources

The information presented on manufacture import and export and uses and relases from uses is based on the RAR with additional data supplied by the HBCD Industry User Group in October 2008. This additional data comprises summary data for the total sales and consumption of HBCDD across the EU for each year from 2003 until 2007, a breakdown of the consumption of HBCDD by the two main uses (XPS and EPS) and an indication of how many sites manufacture XPS or EPS in each member state.

The information on possible alternatives to HBCDD presented in Work Package 3 has been taken from a wide variety of sources including reviews undertaken by both industry and regulators that have aimed to identify candidate substances/techniques.

As agreed with ECHA, this report does not cover cyclododecane as the Member State Committee has unanimously agreed that there was not sufficient scientific data to justify identification under Article 57 of the REACH Regulation.

Information on manufacture, import and export and releases from manufacture

HBCDD is presently only produced at one site in the Netherlands. The production volume varies from year to year. In 2006, it was about 6,000 tonnes. The EU-wide consumption of HBCDD in 2007 was 11,000 tonnes, implying net imports to the EU of about 5,000 tonnes. It is unclear how much HBCDD is actually imported and exported to and from the EU. There was a general trend towards increasing use of HBCDD between 2003 and 2007. Although, it seems likely that 2008 levels of production and importation will be slightly greater than in 2006, the expected recession may depress demand in 2009. In the longer term, there are moves to phase out the use of brominated compounds in the Nordic countries.

About 1,000 tonnes per annum are “micronised” in the EU to produce fine particles for specific applications. This was undertaken at a plant in Belgium. It is possible that micronising is also undertaken at other locations. It is unlikely that the increased use of HBCDD in the EU will have created an increased requirement for micronisation and the reduced use of HBCDD in textile coating may have led to a reduction in the amount being micronised.

Releases of HBCDD to the environment from manufacturing are small. It is estimated that about 3 kg a year are released from the workplace plus a further 2 kg to air and 0.1 kg to waste water. It is estimated that less than 1 kg per year is released from the working environment and that emissions to air are <1 kg/year. The estimated releases from manufacturing are based on the RAR. It is possible that, with increased production, release rates have increased.

Information on uses and releases from uses

HBCDD is solely used as an additive flame retardant. HBCDD is used in four principal product types:

- Expanded Polystyrene (EPS)
- Extruded Polystyrene (XPS)
- High Impact Polystyrene (HIPS)
- Polymer dispersion for textiles

The HBCDD Industry Users Group have been unable to supply information on the proportions of HBCDD currently used for different purposes in the EU. Most is used in EPS and XPS and in 2006, there was a slightly greater proportion used in XPS than in EPS (ratio about 52:48). These products are used widely across the EU in the workplace and in consumer products. The use of XPS and EPS insulation products increased between 2003 and 2007. As a first approximation, it has been assumed that all Masterbatch has been used in XPS manufacture. Masterbatch production accounts for 12% of HBCDD use.

It is believed that the use of HBCDD in HIPS is small, less than 10% of total use and that the use in textiles is also small. The use of HBCDD in textiles is believed to have fallen substantially in recent years. Although industry initially provided an estimate of use in textiles in 2007 as 2% of total use, they subsequently indicated that they were uncertain as to the reliability of this estimate. In the absence of other information, however, we have based our estimates of releases on the estimated use level originally provided. Textile formulators are based largely in Belgium, Germany and the UK. XPS and EPS are manufactured throughout much of Europe: Austria, Belgium, Czech Republic, Finland, France, Germany, Greece, Hungary, Italy, Netherlands, Poland, Portugal, Serbia, Spain, Sweden and the United Kingdom.

The estimated releases of HBCDD to the environment during the manufacture and formulation of HBCDD are 41 kg to air, 60 kg to waste water and 35 kg to surface water per year based on consumption figures for 2006 supplied by the HBCD Industry Users Group.

The release of HBCDD from products during end use is small. Some dust containing HBCDD will be released during the installation of EPS or XPS insulation and ultimately during the refurbishment or demolition of buildings containing these products. Most of the HBCDD released is from coating textiles. The estimated annual release to the environment is 530 kg to air, 1,140 kg to waste water and 560 kg to surface water. The end use releases to waste water and surface water are dominated by textile coating. These estimates are based on consumption figures for 2006 supplied by the HBCD Industry Users Group. The quantities of waste product sent for disposal are uncertain.

Estimated releases of HBCDD during the consumer use of products are highly uncertain. Releases from waste disposal are difficult to estimate because of the long lifetime of XPS and EPS once installed in buildings (potentially up to 50 years) combined with an increasing trend towards the recycling of electrical equipment. The release estimates for consumer use are 54 kg to air, 24 kg to wastewater and 5 kg to surface water. These estimates are based on the RAR, adjusted for recent consumption figures supplied by the HBCD Industry Users Group. They exclude waste disposal.

Information on Alternative substances and techniques

A number of alternative fire retardants are available to replace HBCDD in HIPS but they all require to be used at considerably higher loadings. At present, no suitable flame retardant is available to replace HBCDD in its main end uses in XPS or EPS as the required loadings of alternative flame retardants impair the structure and properties of the finished product to the extent that is no longer suitable for use. There are however a number of alternative forms of insulation that can be used in place of XPS or EPS. These alternative insulation systems have different characteristics to XPS and EPS and may be less appropriate for some specific use scenarios or may incorporate different environmental issues such as increased energy costs during transportation. Given that HBCDD is not widely used in HIPS, it is perhaps reasonable to assume that some technically and economically feasible alternatives are already on the market, although it is uncertain whether the human health and environmental impacts of these alternatives are any less than those associated with HBCDD products.

There are a wide range of different flame retardant formulations in textile coatings and, as with HIPS, it seems likely that some technically and economically feasible alternatives are already on the market, although it is similarly uncertain whether the human health and environmental impacts of these alternatives are any less than those associated with HBCDD products.

The table below summarises the health and environmental information available for the suggested alternatives to HBCDD.

Use	**Alternative**	**Human health**	**Environment**
HIPS	Antimony trioxide (ATO)	Potential human carcinogen and reproductive toxicant	Not readily biodegradable, low to moderate bioaccumulation potential
	Decabromo-diphenylether/ATO	Neurotoxicant	Not readily biodegradable, low to moderate bioaccumulation potential
	Decabromo-diphenylethane/ATO	Limited data, but likely to be of low toxicity	Not readily biodegradable, may be persistent
	Ethylenebis-(tetrabromo phthalimide)/ATO	Low toxicity	Not biodegradable and is persistent. Non-toxic.
	Triphenyl phosphate	Chronic toxicant with effects on liver	Readily biodegradable, toxic to aquatic organisms
	Resorcinol bis (biphenyl phosphate)	Chronic toxicant with effects on liver	Inherently biodegradable, may be persistent and bioaccumulative
	Bis phenol A bis (biphenyl phosphate)	Limited data, likely to be of low toxicity	Poorly biodegradable. Non-toxic and is not bioaccumulative
	Diphenyl cresyl phosphate	Chronic toxicant with effects on liver, kidney and blood. Effects on fertility	Readily biodegradable

Use	Alternative	Human health	Environment
	Polyethylene with Magnesium Hydroxide	Insufficient data but likely to be of low toxicity	Polythene particles are highly persistent in the aquatic environment and may contribute to reduced nutritional intake by organisms; the release of large quantities of magnesium hydroxide to the environment could cause localised problems of water/soil alkalinity.
Textiles	Decabromo-diphenylether	Neurotoxicant	Not readily biodegradable, low to moderate bioaccumulation potential
	Chlorinated paraffins	Reproductive toxicant, chronic toxicity with effects of liver and kidneys, potential carcinogen	LCCPs are considered to potentially meet the persistent or very persistent criterion. They do not meet the toxic or bioaccumulative criterion.
	Ammonium polyphosphates	Low toxicity	Not an ecotoxicant
EPS/XPS	Phenolic Foam	Low toxicity in use but manufactured from materials toxic and carcinogenic	Highly persistent material, long term disposal to landfill with potential for dust emissions to air and surface water, no recycling at present
	Polyurethane and polyisocyanurate products	May emit toxic fumes if burnt, otherwise low toxicity in use, but manufacture involves the use of isocyanates – potent respiratory sensitisers	Highly persistent material, long term disposal to landfill with potential for dust emissions to air and surface water, no recycling at present
	Alternative insulation - Thermal barriers - Loose-fill insulation - Blanket insulation May incorporate glass wool, rock wool, gypsum board	Relatively minor health issues - Inhalation of low toxicity dust generated during installation and removal; no significant emissions while in use in buildings	Materials can be recycled post-consumer use

This report has been produced according to a format and structure provided by ECHA. Draft reports have been reviewed and commented on by ECHA and this final report has been accepted by ECHA.

INFORMATION ON MANUFACTURE, IMPORT AND EXPORT AND RELEASES FROM MANUFACTURE

1.1 Manufacturing sites and manufacturing processes

1.1.1 Production

The production of HBCDD is a batch-process. Elementary bromine is added to cyclododecatriene in the presence of a solvent. The process temperature is 20 to 70°C, and the reaction takes place in closed systems. These materials are mixed to form a slurry that must be extensively washed in order to generate high purity HBCDD. The slurry is centrifuged, the liquids removed for reprocessing and the solid faction is dried, stored in a silo and packed. According to one producer, production and transportation of the material to silo and the packaging are done in a closed system. The product is delivered as powder or pellets.

The production method as described in general terms in the IUCLID Data Sheet is as follows:

- Loading of raw materials
- Bromination
- Filtering
- Drying
- Storage in silo
- Packaging

1.1.1.1 Locations

HBCDD is presently only produced at one site in the Netherlands. Two other production sites were closed for production in the autumn of 2003 and June 1997 respectively (RAR, EC 2008a).

1.1.1.2 Tonnage

The reported amount of HBCDD produced at the production site in the Netherlands varies from one year to another. The total annual (2005) production of HBCDD was assumed to be 6,000 tonnes in the RAR (EC, 2008a).

1.1.2 Micronising

1.1.2.1 Process

The HBCDD particles in some applications (e.g. for use in textile back-coating) need to be very small. Therefore some quantities of HBCDD are micronised in a grinding process.

1.1.2.2 Locations

No information on where micronising takes place is available, but is the RAR assumed that it occurs at a very limited number of sites.

1.1.2.3 Tonnage

The total amount of HBCDD used for micronising was about 1,000 tonnes per year between 2000 and 2004, based on information from the textile industry (RAR). The main use for micronised HBCDD was textile coating. The industry has informed us that this use has dropped by 80% and it is likely that the production of micronised HBCDD has also reduced. Up to date production figures are not, however, available.

1.2 Import and export of HBCDD on its own or in preparations

1.2.1 On own

1.2.1.1 Imports

The HBCDD Industry working group has provided data on the consumption of HBCDD in the EU that includes all EU27 countries (Table 1.1).

Table 1.1: Sales and consumption of HBCDD in the EU in 2007 (HBCDD Industry Users Group, 2008)

Year	Sales in EU Countries tonnes	Estimated EU Consumption tonnes
2003	9,448	9,600
2004	10,123	9,750
2005	10,622	11,000
2006	10,075	11,580
2007	11,186	11,000

There was an increase in HBCDD sales between 2003 and 2007 of about 18%. It is unclear whether this trend would be likely to continue given the growing concern about the presence of brominated fire retardants in the environment and the moves in Nordic countries to phase out their use. Production of HBCDD between 2003 and 2007 was fairly static at 6000 tonnes, implying an increase in net imports of almost 50% over this period. Estimates of EU consumption are slightly different. They imply an increase of almost 15% between 2003 and 2007 with net imports increasing by almost 40%. The best estimate of imports of HBCDD in 2006 is 5,580 tonnes.

1.2.1.2 Exports

It is unclear whether any HBCDD is exported out of the EU as a simple substance. Given the proximity of the production plant to major port facilities, it is likely that some HBCDD would be exported outwith the EU as well as transported within the EU.

1.2.2 In preparations

1.2.2.1 Imports

It is unclear whether HBCDD is imported into the EU in the form of masterbatch and plastic compounds.

1.2.2.2 Exports

It is unclear whether HBCDD is exported out of the EU in the form of masterbatch and plastic compounds. Some export to other European countries that are not part of the EU would seem likely.

1.3 Import and export of articles containing HBCDD

HBCDD contained in expanded polystyrene (EPS) and extruded polystyrene (XPS) for the construction industry is not likely to be transported long distances due to the bulkiness of the material. Furthermore, the extrusion and expansion processes are relatively straightforward industrial processes, which allow them to be carried out in the region where the products are needed. Transport of compounded polystyrene (PS) with HBCDD (granules, masterbatch or beads) over long distances cannot be excluded, but information on this is lacking.

Packaging material containing HBCDD (e.g. EPS) to protect sensitive equipment is likely to be transported worldwide. High impact polystyrene (HIPS) containing HBCDD is likely to be imported to the EU in electrical and electronic equipment, but no data on this has been submitted. Textile that is back-coated with a HBCDD-containing layer is imported from the US and other countries in unknown quantities. Import of polymer dispersions for textiles containing HBCDD cannot be excluded. In summary, import (and export) of HBCDD in articles is likely to occur but has not been possible to quantify.

No up to date information on the export of HBCDD from the EU is available.

1.4 Releases from manufacture

1.4.1 Production

1.4.1.1 Releases to working environment

During production of HBCDD, there is potential for exposure to HBCDD during packing, compaction (to form granules), when process operators have to enter the centrifuge or dryers, and, to a lesser extent, during handling of packaged HBCDD in the warehouse.

Personal exposures to dust and HBCDD were measured in the production facility in the Netherlands by Searl and Robertson (2005) using the methods for respirable[1] and inhalable[2] dust described in MDHS 14/3 (UK Health and Safety Executive, 2000).

The results of the monitoring are summarised in Table 1.2. A total of 10 measurements of personal exposures were made during packing, compaction process operations and warehouse work. In this exercise, compaction gave the highest dust and HBCDD concentrations. The plant does not produce HBCDD continuously throughout the year and the proportion of shifts on which workers are exposed to HBCDD varies from year to year. It is believed that exposure occurs on less than 1 in 4 shifts.

Table 1.2: Personal exposure concentrations measured for workers producing HBCDD

All Production Workers	**Dust concentration (mgm^{-3})**		**HBCDD concentration (mgm^{-3})**	
	Respirable	**Inhalable**	**Respirable**	**Inhalable**
Mean (Standard deviation)	0.4 (0.2)	3.2 (1.2)	0.18 (0.16)	1.23 (0.76)
Median	0.25	2.50	0.05	0.89
90th Percentile	0.70	4.29	0.40	1.86

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[1] That part of airborne dust that can be deposited within the gas-exchange region of the lung

[2] That part of airborne dust that can deposited within the respiratory system

Dermal exposure during production was assessed in the RAR (EC, 2008a) using the EASE occupational exposure model (Tickner et al., 2005). It is assumed that exposure at the manufacture of HBCDD occurs principally during packing and compaction of the product. It was assumed that both hands are exposed. The calculated dermal exposure was 840 mg/day when handling powders and 84 mg/day when handling granules which are coarser and less dusty. Protective suits and gloves are reported to be used in these production processes (Searl and Robertson, 2005) and it is reasonable to reduce these exposures by a factor of 5 to 170mg/day and 17 mg/day to take account of the protection offered by the protective gloves.

1.4.1.2 Releases to environment

Site-specific information on the annual release of HBCDD to air and wastewater is available for the one remaining manufacturing site in the EU, located in the Netherlands.

The annual release 2001 was 6.2 kg mainly via wastewater to a STP (Sanders, 2002). The annual release to wastewater has been reported to be 0.73 kg (2002), 0.13 kg (2003) and 0.20 kg (2004) (Tange, 2005). The highest release figure (0.73 kg/year) from year 2002-2004 was taken in the RAR as a reasonable measure of the emissions to wastewater from this site. It is not clear whether the increase in sales in the EU comes from increased production or greater imports. From the RAR (EC, 2008) the emissions from the production site to water decreased over the period 2002 to 2004, during which time the sales of HBCDD increased. As a worst case estimate the emissions from the risk assessment report could be retained.

The emission to air is 21.7 kg/year, according to site-specific data (Tange, 2003). The site has installed an “absolute filter” for outgoing air. First measurements indicate that particulate emissions to air now are lower than 0.03 mg/m^3. Using a worst-case assumption (assuming all dust would be HBCDD) this would correspond to less than 2 kg/year emissions to air.

No information has been submitted on the formation of solid waste containing HBCDD, but information is provided noting that waste from the production, including sludge from the STP, is disposed of by incineration or reused in the process.

Since there is only one active producer in the EU, the emissions from this site were used in the RAR for the estimation of regional background concentrations. The resulting total, regional and continental emissions from production of HBCDD are given in Table 1.3.

Table 1.3: Total, regional and continental emissions from production of HBCDD.

	Total (kg/year)	**Regional (Netherlands) (kg/year)**	**Continental (kg/year)**
Air	2	2	0
Wastewater	0.73	0.73	0
Surface water	0	0	0

1.4.2 Micronising

1.4.2.1 Releases to working environment

Searl and Robertson (2005) measured personal exposures to HBCDD during micronising in one plant. Dust exposure occurred mainly during the loading and unloading of the grinding rig and when spills were cleaned up using a brush and shovel. The plant handled a variety of materials and micronising HBCDD was only one of several activities undertaken by workers. Exposure to HBCDD therefore did not occur on every shift, although no quantitative information about the proportion of shifts on which HBCDD was handled is available. It is believed that exposure is likely to occur on less than 1 in 4 shifts.

Four samples were collected and the measured personal exposure concentrations of inhalable dust and HBCDD were high, with inhalable HBCDD concentrations averaging 22.7 mgm^{-3} (Table 1.4). HBCDD accounted for virtually all the inhalable dust. Only a small proportion of inhalable dust was within the respirable size fraction.

Table 1.4: Personal exposure concentrations for workers involved in grinding HBCD

	Dust concentration (mgm^{-3})		**HBCD concentration (mgm^{-3})**	
	Respirable	**Inhalable**	**Respirable**	**Inhalable**
Mean (standard deviation)	0.78 (0.21)	23.8 (11.8)	1.43 (0.64)	22.7 (12.3)
90th Percentile	0.94	34.8	1.98	34.6

Dermal exposure during micronising was estimated in the RAR using the EASE model. The reasonable worst-case dermal exposure was estimated as 4,200 mg/day, when no PPE is used. Gloves and protective clothing, which were worn during surveys undertaken by Searl and Robertson (2005), will reduce that figure to 840 mg/day.

1.4.2.2 Releases to environment

Data from one site with micronising have been submitted from Industry (Esser *et al.*, 2003). According to industry this site uses the major part of the amount of HBCDD processed by micronising.

Local emissions

No water is used in the process; except for the cleaning-water, which is collected in a tank and disposed of via a “waste management treatment company”. It is therefore assumed that there are no emissions to wastewater or surface-water.

The emission to air from the site that submitted data was determined to be 0.3 kg/year based on site-specific data (Esser *et al.*, 2003). No data on the number of emission days per year are given so the RAR used the TGD (Technical Guidance Document) default value from the B-tables (300 days/year).

Regional and continental emissions
Based on the information given by industry that the site for which data are given is the by far largest microniser, it is assumed that the emissions from possible other sites involved in micronising are negligible. Thus, the continental release is assumed to be zero.

The resulting total, regional and continental emissions of HBCDD for micronising are given in Table 1.5.

Table 1.5: Total, regional and continental emissions of HBCDD from micronising

	Total (kg/year)	**Regional (kg/year)**	**Continental (kg/year)**
Air	0.28	0.28	0
Wastewater	0	0	0
Surface water	0	0	0

1.5 Unintentional formation

There is no information on the unintentional formation of HBCDD during incineration, by transformation/degradation, or through other processes. Any unintentional formation of HBCDD is likely to be in negligible amounts.

INFORMATION ON USES AND RELEASES FROM USES

2.1 Identification of uses

HBCDD is solely used as an additive flame retardant. HBCDD is used in four principal product types:

- Expanded Polystyrene (EPS)
- Extruded Polystyrene (XPS)
- High Impact Polystyrene (HIPS)
- Polymer dispersion for textiles

The HBCDD Industry Users Group have been unable to supply information on the proportions of HBCDD currently used for different purposes in the EU. Most is used in EPS and XPS and in 2006, there was a slightly greater proportion used in XPS than in EPS (ratio about 52:48). It is believed that the use of HBCDD in HIPS is small, less than 10% of total use and that the use in textiles is also small. The use of HBCDD in textiles is believed to have fallen substantially in recent years. The use of HBCDD in textiles is believed to have fallen substantially in recent years. Although industry initially provided an estimate of use in textiles in 2007 as 2% of total use, they subsequently indicated that they were uncertain as to the reliability of this estimate. In the absence of other information, however, we have based our estimates of releases on the estimated use level originally provided. As a first approximation, it has been assumed that all Masterbatch has been used in XPS manufacture. Masterbatch production accounts for 12% of HBCDD use.

2.1.1 Masterbatch

Masterbatch is a concentrated mixture of HBCDD encapsulated during a heat process into a carrier resin (polystyrene) which is then cooled and cut into a granular shape. It is used to manufacture end products such as XPS or HIPS. Masterbatch contains a higher concentration of HBCDD than the final product made from it.

2.1.2 Expanded Polystyrene

Expanded Polystyrene (EPS) is a rigid cellular plastic, which is used in a multitude of applications such as packaging. HBCDD-containing EPS is mainly used for the following purposes:

- insulation panels/boards in the construction sector
- automobile cushions for children (KemI, 1994) to meet the needs of the FMVSS 302 standard
- rigid packaging material for fragile equipment (minor use)
- packaging material such as “chips” and shaped EPS-boards (minor use)
- in props for theatre and film, and in exhibitions (minor use)

Expanded polystyrene is produced in a batch process by suspension polymerisation of styrene in water. Prior to combining the water with the organic phase, additives are introduced such as suspension agents, free-radical forming initiators and HBCDD. HBCDD powder, most often delivered in 25kg paper bags with a plastic liner, is suspended at low temperatures in styrene prior to the addition of the water phase. Normally the bags are emptied into an intermediate storage container from where the

HBCDD is transported via pipes and a weighing station prior to the addition to the styrene.

In the reactor, styrene forms the disperse phase as small monomer droplets in the continuous water phase. Final droplet size (0.01 to 0.5 mm) is determined by the ratio of disperse to continuous phase (typically 50:50) and by stirrer speed. Within the monomer droplets (bulk), polymerisation occurs while the reactor content is heated up and held at its reaction temperature. During this free-radical polymerisation an expansion agent (e.g. pentane) is added to the reactor under pressure, where it is absorbed in the polymer droplets.

HBCDD is incorporated as an integral and encapsulated component within the polymer matrix with uniform concentration throughout the bead.

After complete conversion of the styrene monomer to EPS-beads, the reactor is cooled down and the beads are separated from the water by centrifugation. The decanted water, which could contain dissolved and dispersed HBCDD, is reused and exchanged on an annual basis or less frequently. The EPS beads are dried and classified into various size fractions and surface coated. These different grades are packed in bins, bags, or transported in bulk trucks to the EPS-converters. The maximum concentration of HBCDD in EPS beads is assumed to be 0.7 %.

EPS foam is produced from EPS beads through pre-expansion of the beads with dry saturated steam, drying with warm air and shaping in shape moulds or in a continuous moulding machine. First, the raw material beads are pre-expanded in loose form with the help of dry saturated steam in pre-expanders. The raw materials are transported via pipes or tubes from the packaging containers to these stirred vessels. After expansion the beads are partly dried in fluid bed driers with warm air. The beads are subsequently stored in large permeable silos to “mature” for up to 24 hours. During this stage the beads dry further and reach equilibrium with the ambient atmosphere around them. In the third phase the beads are transported/blown, via pipes/tubes into block or shape moulds or in a continuous moulding machine in which the product gets its shape. The foam can then be further formed by cutting, sawing or other machine operations.

2.1.3 Extruded Polystyrene

Extruded polystyrene (XPS) is a plastic foam based on polystyrene that is formed by adding gas during extrusion. HBCDD-containing XPS is mainly used for the following purposes:

- Cold bridge insulation
- Sandwich Panels and Laminates
- Cavity Insulation
- Floors
- Basement Walls and Foundations
- Inverted Roofs
- Ceilings

The manufacture of XPS materials is carried out in the following way:

1. The polystyrene, the additives such as processing aids, flame retardant, dye and blowing agent are fed continuously to an extruder.
2. The polymer is melted; the blowing agent is mixed with the melted polymer and a “foamable gel” is formed.
3. The gel is then cooled before it exits through an orifice called a die, where the blowing agent volatilises, causing the plastic to assume a foam structure. The blowing agent is usually a volatile, chemically stable compound, and by its introduction into the molten polymer, it reduces the density of the product by the formation of a myriad of closed cells within its structure.
4. The foam is then trimmed to desired shape. The boards are packed into shrink-wrapped bundles and palleted. The pallets are stored for curing (usually 1 week) and are then ready for shipment.
5. A remainder of about 25 % of the material is recycled to the extruder. This material is mainly “skin” from the surface, with higher density. The recycled material comes in contact with water.

The HBCDD is supplied either in powder or in low-dust granulated form in either 25 kg bags or in 1 tonne supersacks or “big bags”. The supersacks are emptied into hoppers designed to minimise dust emissions. The HBCDD is then carried to the point of mixing with screw or air driven metering equipment. The compounded polystyrene is extruded and cut into granules, and packaged. The extrudate is either air-cooled or cooled by running in a water bath.

One technology usually known as the UCI technology uses a vacuum in addition to blowing agents to produce lighter (lower density) foams. In this technology, the product comes into contact with water in a water pond directly after the extrusion.

2.1.4 High Impact Polystyrene

Most flame-retarded High Impact Polystyrene (HIPS) products are used in electrical and electronic appliances. For example:

- audio visual equipment cabinets (video and stereo equipment)
- distribution boxes for electrical lines in the construction sector
- refrigerator lining

HIPS pellets are produced either in a batch or continuous polymerisation process. HBCDD powder, delivered in plastic bags, is filled in intermediate storage containers. HBCDD and other ingredients required for the particular HIPS formulation are weighed and transported to the feeding hopper of the extrusion equipment where they undergo further mixing, homogenisation and granulation into pellets.

An alternative route for HIPS pellet production is via an intermediate-compounding route. Masterbatch (as detailed in section 2.1.1) is compounded with non flame-retarded HIPS material in a conversion step.

After the molten mass at the end of the extruder is pressed through a plate with holes (die/plate), different granulation processes take place, for example:

- face cutting in air; a rotating knife directly after the plate cut the extruded “strands” into pellets cooled by air.

- under water face cutting; a rotating knife directly after the plate in a water bath cuts the extruded strands in pellets cooled by water.
- strand cutting; the molten strands are passed through a water bath to solidify and cool and are cut in a granulator.

After the granulation process the HIPS pellets are dried and packed, either in bulk silos/containers or 25 kg bags, ready for conversion into HIPS products.

HIPS materials can be converted into HIPS products using various extrusion techniques and injection moulding. HIPS products can also be manufactured via a compounding route, i.e. mixing non flame-retarded HIPS raw material with a HBCDD masterbatch during the extrusion or injection moulding process.

The HBCDD content of flame-retarded HIPS is 1 - 3 % (w/w) (BASF, 1996) or in other cases 5 or 7 % (Albemarle, March 1996). In the RAR (Swedish Chemicals Agency, 2008), it was assumed for the calculations of exposure, as a realistic worst case, that HIPS contains 7 % HBCDD.

2.1.5 Textile Coating

Flame retardant systems are used in textile applications to comply with British Standard and German DIN flame retardant standards. HBCDD is formulated to polymer-based dispersions (e.g. acrylic or latex) of variable viscosity in the polymer industry. The dispersions are then processed in the textile finishing industry. The textiles with the back-coating containing HBCDD are mainly used for:

- flat and pile upholstered furniture (residential and commercial furniture)
- upholstery seating in transportation
- draperies, and wall coverings
- bed mattress ticking
- interior textiles e.g. roller blinds
- automobile interior textiles and car cushions.

The HBCDD particles used for textile back-coating need to be very small and micronised (see chapter 2.1.2). Flame retarded formulations containing HBCDD are prepared as water-based dispersions that can contain a binder system and HBCDD as well as up to 20 other ingredients. These flame retarded formulations, mostly custom tailored, are supplied as a dispersion to back-coaters. In this scenario, formulation is carried out in an open batch system. HBCDD is added to a dispersion containing water, a polymer e.g. synthetic latex, acrylates or PVC, thickener and dispersion agent. The chemical preparation can also contain other brominated flame-retardants such as decabromodiphenyl ether. In addition, synergists such as antimony trioxide and antimony pentoxide may also be included in the end-product. According to industry information, the concentration of HBCDD in the dispersion may range from 5 to 48 %. However, additional product information indicates that a likely concentration of HBCDD in the coated layer may be about 25 % corresponding to 10 - 15 % in the final dilution of the dispersion. Water and solvents will leave the preparation when dried and concentrations of flame-retardants in the coating layer will be higher than in the preparation. Preparations with the highest concentration of HBCDD are assumed to be diluted before use.

The water based dispersion used by the back-coaters needs to be stable (no precipitation and no viscosity change) and should not contain particles that could clog the coating system. Therefore, the particle size of the solids is very important. Particles that are too fine act as a thickener, whereas particles that are too large will lead to a non-stable dispersion (precipitation) and an applied coated film with an unacceptable rough surface.

Back-coating to textile can be applied in the following ways:

1. as a paste where a layer is “glued” to the textile and a scratch knife defines the final thickness depending on the flame retardant standard, the textile used and the flame retardant concentration in the dispersion; or
2. as a foam, where a foam layer is pressed on the textile through a rotating screen. Once applied the foam cells will break resulting in a thin coating film.

The coating is dried and fixated in an oven at temperatures between 140 to 180 °C, (Delgado and (EIPPCB, 2003).

The formulated product is used on technical textile and furniture fabric, on cotton fabrics, and on cotton polyester blends. For the calculations of exposure, the RAR assumed that the backcoating layer of the finished textile contains 25 % HBCDD. HBCDD is usually applied with antimony trioxide as a back-coating in a mass ratio of 2:1 (i.e. about 6-15 % HBCDD and 4-10 % antimony oxide by weight) (National Research Council, 2000).

2.2 Quantification of uses

2.2.1 Inventory Table

The figures in Table 2.1 below are taken from the risk assessment report (EC, 2008). They relate to the EU-15 countries. The values come from a range of years, but were considered in the RAR (EC, 2008a) to be representative of the period 2000-2004.

Table 2.1: Inventory of HBCDD use in the EU15 in 2000-2004 (Swedish Chemicals Agency, 2008)

Use	**Tonnes/year**	**No. of users**	**Geographical distribution**
EPS formulators	3392	18	Unknown
EPS industrial users	3392	100s	Across Europe
XPS formulators	1730	14 approx	9 in Italy 1 in Germany 1 in Austria 1 in UK 1 in Belgium 1 unknown
XPS industrial users	4962	35	Across Europe
HIPS formulators	210	3	Unknown
HIPS industrial users	210	18	Unknown
Textile coating formulators	1050	16	7 in UK 5 in Belgium 4 in Germany
Textile coating industrial users	1050	24	15 in Belgium 9 in UK

Masterbatch quantities are included under the relevant polystyrene type.
Most HBCDD used in XPS is used as powder at the industrial use stage, rather than being included in a compound at the formulation stage.

More recent data for EPS and XPS in the EU27 in 2007 has been provided by the HBCDD industry user group (31/10/2008). The total tonnage of HBCDD used in XPS and EPS in the EU as a whole has increased over the last 5 years which presumably reflects the growing use of XPS and EPS in construction (Table 2.2).

Table 2.2: Use of HBCDD in EPS and XPS in the EU (tonnes)

Year	EPS	XPS
2002	3,452	3,954
2003	4,053	4,350
2004	4,270	4,617
2005	4,690	5,123
2006	5,301	5,859
2007	5,652	N/A

Industry data also stated that 2% of HBCDD production went to textile manufacture in 2007, implying that a little over 200 tonnes of HBCDD was used in textiles in 2007.

For the purposes of the estimation of releases to the environment, the 2006 usage figures for EPS and XPS and a 2007 estimate of 210 tonnes for textile coating were used. These figures are used in tables 2 and 3 in Annex 1.

Industry data for 2007 also show that HBCDD is widely used to manufacture EPS and XPS across the EU (Table 2.3).

Table 2.3: Distribution of EPS and XPS manufacturing sites in Europe

Country	Number of sites	
	EPS	**XPS**
Austria	1	1
Belgium	2	1
Czech Republic	2	
Finland	1	
France	1	3
Germany	4	6
Greece	1	1
Hungary	1	1
Italy	1	5
Netherlands	4	1
Norway		1
Poland	1	
Portugal		1
Serbia		1
Spain	2	4
Sweden		1
Turkey		3
United Kingdom		2

The use of XPS and EPS may be slightly reduced in the immediate future (2008-9) because of the downturn in house-building currently affecting much of Europe, but the insulation industry is confident that sales of insulation products will continue to increase in coming years in response to the increasing relative cost of energy and growing awareness of climate change (Global Insulation (international trade association) http://www.propubs.com/GI/Articles/eGI_May08_ExaneBNPParibas.pdf).

2.3 Quantification of releases from uses

2.3.1 Masterbatch

2.3.1.1 Releases into working environment

Exposure to airborne HBCDD during the production of masterbatch is most likely during the mixing of HBCDD product with polystyrene and other additives prior to melting of the mixture. Exposure is also possible during the extrusion of the melt and subsequent processing into granular form for packing.

Searl and Robertson (2005) measured HBCDD during masterbatch production in one plant. Measured personal exposure concentrations were variable. Peak concentrations during the task of mixing and weighing were quite high, but shift mean concentrations were much lower as these dusty tasks were only performed for part of the shift. The extruder operator was exposed to relatively low concentrations of dust and HBCD (Table 2.4). No information is available about patterns of shift rotation and the proportion of shifts on which workers might be exposed.

Table 2.4: Personal exposure concentrations associated with the production of Masterbatch (Searl and Robertson, 2005)

Task	No of samples	Duration (minutes)	Dust Concentration (mgm^{-3})		Concentration of HBCD (mgm^{-3})	
			Respirable	**Inhalable**	**Respirable**	**Inhalable**
Mixing and weighing	10	Mean	0.54	9.24	0.16	1.89
		Standard deviation	0.30	5.43	0.10	2.45
		Median	0.45	7.25	0.17	0.83
		90th percentile	0.72	14.57	0.25	5.35
Extruder operator	4	Mean	0.38	1.73	0.05	0.12
		Standard deviation	0.05	0.19	0.02	0.05
		Median	0.40	1.65	0.05	0.10
		90th percentile	0.40	1.91	0.06	0.16

For dermal exposure, there are no measured data and EASE was therefore used by in the RAR to assess exposure levels. The reasonable worst-case dermal exposure level during the use of fine and standard grade HBCDD was estimated to be 0.1 $mg/cm^2/day$. It was assumed that both hands are exposed in Masterbatch-production, corresponding to an exposed area of 840 cm^2, respectively. This leads to an exposure to 84 mg/day in Masterbatch production. For granules, the exposure is thought to be 10 % of that with powder because it is less dusty. Gloves were routinely worn when pure HBCDD was handled at all plants surveyed by Searl and Robertson (2005). Gloves will reduce dermal exposure and figures of 17 mg/day and 1.7 mg/day are reasonable worst cases for Masterbatch production with powder and granules, respectively.

2.3.1.2 Release into environment

The emissions from the formulation of EPS beads and HIPS compound are dealt with in the same scenario. This is because information received from most of the sites cannot be separated between these two activities.

The emission estimates shown in Tables 2.5 and 2.6 are based largely on site specific information, applying the largest emission factor from actual sites to the use quantity not covered by the specific information. They are taken from the risk assessment report (EC, 2008) and are based on the tonnages used in the period 2000-2004 in the EU15. For the geographical distribution of these uses see Section 2.2.1. They include any emissions from masterbatch. The more recent information on the amounts of HBCDD used in EPS and XPS indicates an increase over the figures from 2000-2004, by 56% for EPS and by 18% for XPS for the 2006 figures. Assuming that the emissions would increase pro rata, the revised emissions would be as in Tables 2.7 and 2.8.

Table 2.5: Total, regional and continental emissions of HBCDD from formulation of EPS beads and HIPS compound (Point sources< RAR)

HBCDD emissions	Total (kg/year)	Regional (kg/year)	Continental (kg/year)
Air	19.5	0.4	19.1
Wastewater	48	0	48
Surface water	212	113.4	98.6

Table 2.6: Total, regional and continental emissions of HBCDD from formulation of XPS compound (Point sources, RAR)

HBCDD emissions	Total (kg/year)	Regional (kg/year)	Continental (kg/year)
Air	11.4	5.7	5.7
Wastewater	71.2	35.6	35.6
Surface water	8.6	4.3	4.3

Table 2.7: Total, regional and continental emissions of HBCDD from formulation of EPS beads and HIPS compound (Point sources, 2006 values)

HBCDD emissions	Total (kg/year)	Regional (kg/year)	Continental (kg/year)
Air	30.4	0.6	29.8
Wastewater	75	0	75
Surface water	330	177	154

Table 2.8: Total, regional and continental emissions of HBCDD from formulation of XPS compound (Point sources, 2006 values)

HBCDD emissions	Total (kg/year)	Regional (kg/year)	Continental (kg/year)
Air	13.5	6.7	6.7
Wastewater	84	42	42
Surface water	10	5	5

EPS

2.3.1.3 Releases into working environment

Release during industrial use

Exposure to HBCDD occurs primarily during the production of EPS when it is added to the reactor.

The RAR (EC 2008a) reported that personal exposures to inhalable dust for five operators at one plant were 0.5 mgm^{-3} for respirable dust (0.5-5 µm) and 2.0 mgm^{-3}for total inhalable dust. Exposures to organic dusts were measured at another European EPS plant. All 22 measurements were less than 6 mgm^{-3} (Ransbotyn, 1999).

In addition, Searl and Robertson (2005) measured inhalation short and long term exposures to HBCDD during the production of EPS in four plants.

Measured short term personal exposure concentrations at two plants for dust and HBCDD during the period of addition of HBCDD were high (Table 2.9).

When these short-term measurements were recalculated into 8 hour average concentrations, the mean and 90th percentile HBCDD concentrations were 1 and 1.3 mgm^{-3} of inhalable HBCDD, respectively. Full shift measurements were conducted (Table 2.7) with the mean and 90th percentile inhalable HBCDD concentrations being 1.39 and 4.91 mgm^{-3} respectively.

Table 2.9: Summary of measured personal exposure concentrations, representative of average exposure over a full shift for process operators undertaking addition of HBCDD to the reactor.

	Number of measurements (plants)	**Dust concentration (mgm^{-3})**		**HBCDD concentration (mgm^{-3})**	
		Respirable	**Inhalable**	**Respirable**	**Inhalable**
Mean	17 (3)	0.42	2.59	0.33	1.18
Standard deviation		1.25	4.01	1.21	3.39
Median		0.10	1.40	0.03	0.27
90th Percentile		0.36	4.29	0.12	1.10

Short term personal exposure concentrations during addition of HBCDD to the EPS reactor were higher, with mean and 90th percentile inhalable dust concentrations of 6.98 and 10.46 mgm^{-3}, respectively. The task lasted 10 to 15 minutes and took place up to four times per shift and these results are not inconsistent with the full shift measurements.

There were no observations recorded regarding the exposure pattern for process workers

Four personal samples collected during weighing of HBCDD for addition to the reactor gave mean and 90th percentile inhalable HBCDD concentrations of 7.2 and 10.5 mgm^{-3} respectively. Although individuals spent up to the whole working day doing this task, a few hours of weighing provides sufficient HBCDD to last for 2 weeks production.

For dermal exposure, there is no measured data and EASE (Tickner et al., 2005) was therefore applied in the RAR to assess exposure levels during industrial use of HBCDD as an additive. The same process was followed as for Masterbatch resulting in figures of 17 mg/day and 1.7 mg/day as reasonable worst cases for EPS production with powder and granules, respectively.

Release during professional and private use

There is no information about occupational exposure to HBCDD during the installation of EPS during construction and other activities. It is likely that inhalable dust concentrations arising from the board will not exceed 10 mgm^{-3} and, as the proportion of HBCDD in EPS is around 1% exposure, inhalable HBCDD concentrations are unlikely to exceed 0.1 mgm^{-3}.

Dermal exposure is very likely to be less than the level of 1.7 mg/day during manufacture of EPS with granules.

Release during service life
There is insufficient information regarding exposure to HBCDD from disturbance of products made from EPS during normal service life. Any exposure from disturbance is likely to very occasional and very low as dust generation is unlikely and the vapour pressure of HBCDD is low.

Consumer exposure to HBCDD from construction boards (EPS or XPS) was calculated in the RAR to be 11.6 µg or 0.11 µg depending on the emission factor used. If the body weight is 60 kg and, if the uptake is 100 %, the internal exposure will be 0.19 or 0.002 µg/kg bwt/day. This exposure was considered insignificant and was not included in the risk assessment.

Release during disposal
Removal of EPS insulation board at the end of its life is likely to be a dusty operation. In buildings, inhalable dust concentrations of more than 10 mgm^{-3} are likely but this will not be a continuous process. It is likely that occupants will not be present during removal. Concentrations will be lower outside. HBCDD constitutes around 1% of this insulation board and, assuming inhalable dust concentrations average 10mgm^{-3}, the exposure concentration of HBCDD to which workers will be exposed will be 0.1 mgm^{-3}.

Insulation boards form the majority of HBCDD containing waste. It is understood that most goes to landfill or incineration. Swan et al (2004) and Krajewski *et al* (2002) reported personal exposures to inhalable dust on several landfill sites to be between 0.3 and 9.0 mgm^{-3}. EPS boards contain around 1% of HBCDD. Given the multitude of dust sources on landfill sites, it is inconceivable that there will be measurable levels of HBCDD attributable to treated insulation boards in these dusts. Exposure to HBCDD from boards at managed incinerator sites is likely to be similarly low.

2.3.1.4 Release into environment

Release during industrial use
The emission estimates shown in Table 2.10 have been taken from the RAR and were derived using the approach in the OECD Emission Scenario Document on Plastics Additives (OECD, 2004) and are based on the use data for the EU15 in 2000-2004. For the geographical distribution of these uses see Section 2.2.1.

Table 2.10: Total, regional and continental emissions of HBCDD from industrial use of EPS compound in the manufacture of flame retarded EPS (Point sources, RAR data)

HBCDD emissions	Total (kg/year)	Regional (kg/year)	Continental (kg/year)
Air	102	10.2	92
Wastewater	82.2	8.2	74
Surface water	20.4	2	18

The more recent information on the amounts of HBCDD used in EPS indicates an increase over the figures from 2000-2004, by 56% for the 2006 figures. Assuming that the emissions would increase pro rata, the revised emissions would be as in Table 2.11.

Table 2.11: Total, regional and continental emissions of HBCDD from industrial use of EPS compound in the manufacture of flame retarded EPS (Point sources, 2006 figures)

HBCDD emissions	**Total (kg/year)**	**Regional (kg/year)**	**Continental (kg/year)**
Air	159	16	144
Wastewater	128	13	115
Surface water	31	3.1	28

Release during professional and private use

HBCDD is used as a flame retardant in polystyrene. The predominant use of polystyrene is in rigid insulation panels/boards for building construction (EPS and XPS).

The private use of articles (e.g. insulation boards) containing HBCDD is small compared to professional use. Emissions from private use are considered to be covered by the calculation of emissions during professional use.

The professional use of insulation boards during construction and renovation of buildings is assumed to result in releases to the environment.

The release of particles from cutting *EPS-boards* was estimated in the RAR to be 100 g particles per tonne of EPS. A total of 3,392 tonnes of HBCDD was used in EPS each year. The RAR concluded that a worst-case estimate therefore results in a yearly release of 339 kg HBCDD from the use of EPS in insulation boards.

In the RAR it was assumed that a total of 4,926 tonnes of HBCDD is used in XPS each year. The release of particles from sawing XPS-boards is estimated to be 5.0 g particles per tonne of XPS. This results in a yearly release of 25 kg HBCDD from the use of XPS in construction.

The RAR estimated that the total yearly release figure is 364 kg of HBCDD from the use of installation boards in construction. The distribution of the release was estimated to be 50% to surface water and 50% to air (Table 2.12).

Table 2.12: Total, regional and continental emissions of HBCDD from installation of professional insulation boards (Diffuse sources, RAR)

HBCDD emissions	Total (kg/year)	Regional (kg/year)	Continental (kg/year)
Air	182	18	164
Wastewater	0	0	0
Surface water	182	18	164

The emission estimates shown in Table 2.12 are taken from the RAR (EC, 2008a) and are based on the tonnages used in the period 2000-2004. For the geographical distribution of these uses see Section 2.2.1. They relate to the EU-15 countries.

The more recent information on the amounts of HBCDD used in insulation boards in EU27 indicates an increase over the figures from 2000-2004, by 30% for the 2006 figures. Assuming that the emissions would increase pro rata, the revised emissions would be as in Table 2.13.

Table 2.13: Total, regional and continental emissions of HBCDD from installation of professional insulation boards (Diffuse sources, 2006 figures)

HBCDD emissions	Total (kg/year)	Regional (kg/year)	Continental (kg/year)
Air	236	23	213
Wastewater	0	0	0
Surface water	236	23	213

Release during service life

The emission estimates shown in Table 2.14 are based on the results of experiment measuring the loss of HBCDD from a sample of foamed polystyrene, assuming an average service life of 30 years.

Table 2.14: Total, regional and continental emissions of HBCDD from building insulation (EPS and XPS) (Diffuse sources)

HBCDD emissions	Total (kg/year)	Regional (kg/year)	Continental (kg/year)
Air	54	5.4	48.6
Wastewater	0	0	0
Surface water	0	0	0

These emissions are taken from the RAR (EC, 2008a) and are based on the tonnages used in the period 2000-2004. They relate to the EU-15 countries, and there is no information regarding use in specific countries. As noted above, there is significant use in Eastern European countries, and so the emissions from the EU-27 may be greater. Applying the same market figures as above, the increased use could be up to 1.3 times that assumed for the calculation in the risk assessment report, or 70 kg/year (to air). Again as noted above, if some of the products used in Eastern Europe come from the Western European production, then the increase would not be as much. The more recent information on the amounts of HBCDD used in insulation boards indicates an increase over the figures from 2000-2004; however, as the estimate of losses from service life is based on a lifetime of 30 years, this increase will not significantly affect the emission estimates for some time.

Release during disposal
Waste generated during the industrial use scenario is generally recycled into the process, put into landfill or incinerated. Emissions from this kind of waste generation are assumed to be included in the release estimates of the TGD for the corresponding life-cycle step. There are no data available.

There may be releases of HBCDD when buildings insulated with flame retarded EPS are demolished. Estimates of possible future emissions from insulation boards to the wider environment at disposal are included in the risk assessment (EC, 2008a). The basis for the estimates is as follows.

For boards which are recovered, possible losses of particulates were based on tests on manual breaking of board samples (information no referenced in EC, 2008a). There were no particulate losses for XPS, and 90 g particulates per tonne for EPS. The proportion of demolition waste recycled was taken as 30% (from RTD information). A quantity of 4,000 tonnes per year of HBCDD in EPS was assumed (as 50% of the 8,000 tonnes of HBCDD used in insulation boards). The resulting emission was 108 kg per year.

For the 70% of boards assumed not to be recycled, an emission factor of 0.1% was used. (This is referenced to Anonymous, 1998 in the risk assessment, but this source does not appear in the reference list. In an earlier draft of the assessment, this source was given as a draft version of the OECD ESD on Plastics Additives (OECD, 2004). However, no such emission factor could be found in that source.) Applying this factor to 70% of the 8,000 tonnes gives an emission of 5,600 kg per year.

The same approaches can be applied to the tonnages for 2006. For use of 5,301 tonnes of HBCDD in EPS, an emission of 143 kg per year (in EPS particulates) is estimated (assuming 30% recycling). For the use of 12,160 tonnes in EPS and XPS, an emissions of 8,5112 kg per year of HBCDD can be estimated for the 70% not recycled.

These estimates assume that the equivalent of one year's production is present in demolition waste each year. The figures apply to the EU27. The estimate of 30% of material recycled has been retained. It could be foreseen that in the future a higher percentage could be recycled (no specific evidence, but based on general trends in recycling). Emissions from recycled material are lower, and hence the above estimates should be a worst case. There are considerable uncertainties in these estimates and it is likely that a substantial proportion of buildings in which flame retarded EPS has been used are less than 30 years old and not likely to be subject to demolition at present or in the near future. EC (2008) suggested that such products had not yet been in use for 30 years. Therefore emissions from this source are unlikely to be significant at present, but may grow in the future, particularly from about 2025 onwards as increasing numbers of buildings containing HBCDD-treated EPS become subject to refurbishment or demolition. There have been no studies of predicted current or future emissions.

2.3.2 XPS

2.3.2.1 Releases into working environment

Release during industrial use

Potential exposure to HBCDD during XPS manufacture occurs when it is added to a hopper that feeds into the polystyrene melt. Further potential exposure to HBCDD contained within polystyrene dust may also occur during secondary processing of XPS and during the shredding and reprocessing of process waste.

Searl and Robertson (2005) measured inhalation exposures to HBCDD in during the production of XPS in four plants. Masterbatch was used as a feedstock in three of these. Results are summarised in Table 2.15 below.

Table 2.15: Data summary for personal exposure measurements made in XPS plants handling Masterbatch (Searl and Robertson, 2005)

Task	**Number of measurements (plants)**	**Measure**	**Dust concentration (mgm^{-3})**		**Concentration HBCD (mgm^{-3})**	
			Respirable	**Inhalable**	**Respirable**	**Inhalable**
Process operators handling Master-batch	24 (3)	Mean	0.16	1.41	0.01	0.03
		90th Percentile	0.20	2.95	0.01	0.03
Other process control operators	4 (1)	Mean	0.10	1.68	0.01	0.03
		90th Percentile	0.10	2.07	0.02	0.03
Secondary processing of boards	9 (2)	Mean	0.13	0.86	0.01	0.08
		90th Percentile	0.31	1.33	0.02	0.22
Reclamation	5 (1)	Mean	0.09	0.75	0.06	0.02
		90th Percentile	0.16	1.50	0.14	0.02

Searl and Robertson (2005) also made exposure measurements at an XPS plant that used HBCDD granules. Measured exposures to HBCDD were all less than 0.1 mgm^{-3} and the highest inhalable dust concentration was 2.1 mgm^{-3}. It was also noted that shift rotation meant that exposure occurred on between only one in five and one in 3 shifts.

The RAR described exposure measurement from eight surveys of the manufacturing of extruded polystyrene (XPS) foam described by Abbot (2001). 95 % of the inhalable and respirable HBCDD concentrations were below 0.47 mgm^{-3}.

Thomsen *et al.*, 2007 analysed HBCDD concentrations in the workplace air and in the workers' serum Ten workers working in the "reactor" or "mixer" areas and ten persons from the general Norwegian population were selected for study. The HBCDD concentrations in air ranged from 0.24 µg.m^{-3} to 150 µg.m^{-3}. The concentrations in the mixer area (mean 0.5 µg.m^{-3}) were significantly lower than those in the reactor area (mean 15 µg.m^{-3}, median). The mean serum concentrations were 162 ng/g lipids and 218 ng/g lipids, for mixer area and reactor area workers, respectively. HBCDD was not detected above the limit of detection (LOD = 0.5 ng/g lipid) in any serum samples from the control group.

For dermal exposure, there are no measured data and EASE was therefore used by in the RAR to assess exposure levels during industrial use of HBCDD as an additive. The same process was followed as for Masterbatch resulting in figures of 17 mg/day and 1.7 mg/day as reasonable worst cases for XPS production with powder and granules, respectively. As Masterbatch contains around 50% HBCDD, a reasonable worst case for XPS production using Masterbatch would be 0.9 mg/day, half of that for XPS production using HBCDD granules.

Release during professional and private use

There is no information about occupational exposure to HBCDD during the installation of EPS during construction and other activities. It is likely that inhalable dust concentrations arising from the board will not exceed 10 mgm^{-3} and, as the proportion of HBCDD in EPS is around 1% exposure, inhalable HBCDD concentrations are unlikely to exceed 0.1 mgm^{-3}.

Dermal exposure is very likely to be less than the level of 1.7 mg/day during manufacture of EPS with granules.

Release during service life

Any exposure to HBCDD from disturbance of products made from XPS during normal service life is likely to very low and very occasional as dust generation is unlikely and the vapour pressure of HBCDD is low.

Consumer exposure to HBCDD from construction boards (XPS or EPS) was calculated by the RAR to be 11.6 µg/day or 0.11 µg/day depending on the emission factor used. If the body weight is 60 kg and, if the uptake is 100 %, the internal exposure will be 0.19 or 0.002 µg/kg bwt/day. This exposure was considered insignificant and was not included in the risk assessment.

Release during disposal

Removal of XPS insulation board at the end of its life is likely to be a dusty operation. Assuming there is approximately 1% HBCDD in XPS board and that inhalable dust concentrations would average 10mg m^{-3}, the concentration of HBCDD to which workers will be exposed will be 0.1 mgm^{-3}. It is likely that occupants will not be present during removal.

Insulation boards form the majority of HBCDD containing waste. It is understood that most goes to landfill or incineration. Swan et al (2004) and Krajewski *et al* (2002) reported personal exposures to inhalable dust on several landfill sites to be between 0.3 and 9.0 mgm^{-3}. XPS boards may contain up to a few percent of HBCDD. Given the multitude of dust sources on landfill sites, it is inconceivable that there will be measurable levels of HBCDD attributable to treated insulation boards in these dusts. Exposure to HBCDD from boards at managed incinerator sites is likely to be similarly low.

2.3.2.2 Release into environment

Release during industrial use

The sites producing flame retarded XPS use HBCDD either as powder or as a compound. The emission estimates shown in Tables 2.16 and 2.17 have been taken from the RAR and are based on site specific information, applying the largest emission factor from actual sites to the use quantity not covered by the specific information. They are based on the tonnages used in the period 2000-2004. For the geographical distribution of these uses see Section 2.2.1 and relate to the EU-15 countries. The more recent information on the amounts of HBCDD used in XPS indicates an increase over the figures from 2000-2004, by 18% for the 2006 figures. Assuming that the emissions would increase pro rata, and that the distribution between compound and powder remains the same, the revised emissions would be as in Table 2.18 and 2.19. The best estimate of the current total release to the environment during the manufacture of flame retarded XPS is the sum of the figures in tables 2.18 and 2.19.

Table 2.16: Total, regional and continental emissions of HBCDD from industrial use of XPS compound in the manufacture of flame retarded XPS (Point sources)

HBCDD emissions	Total (kg/year)	Regional (kg/year)	Continental (kg/year)
Air	100	20	80
Wastewater	27	5.4	21.6
Surface water	7	1.4	5.6

Table 2.17: Total, regional and continental emissions of HBCDD at sites involved in industrial use of HBCDD powder for flame retarded XPS (Point sources)

HBCDD emissions	Total (kg/year)	Regional (kg/year)	Continental (kg/year)
Air	23.6	2.1	21.5
Wastewater	26.4	16.9	9.5
Surface water	6.6	4.2	2.4

Table 2.18: Total, regional and continental emissions of HBCDD from industrial use of XPS compound in the manufacture of flame retarded XPS (Point sources, 2006 figures)

HBCDD emissions	Total (kg/year)	Regional (kg/year)	Continental (kg/year)
Air	118	24	94
Wastewater	32	6.4	25
Surface water	8.3	1.7	6.6

Table 2.19: Total, regional and continental emissions of HBCDD at sites involved in industrial use of HBCDD powder for flame retarded XPS (Point sources, 2006 figures)

HBCDD emissions	Total (kg/year)	Regional (kg/year)	Continental (kg/year)
Air	28	2.5	25
Wastewater	31	20	11
Surface water	7.8	5	2.8

Release during professional and private use

HBCDD is used as a flame retardant in polystyrene. The predominant use of polystyrene is in rigid insulation panels/boards for building construction (EPS and XPS).

The private use of articles containing HBCDD (e.g. insulation boards) is small compared to professional use. Emissions from private use are considered to be covered by the calculation of emissions during professional use.

Please see Section 2.3.2.2 for details on the release of HBCDD from the professional use of XPS boards and EPS boards in construction.

Release during service life

Please see Section 2.3.2.2 for the total, regional and continental emissions of HBCDD from building insulation (EPS and XPS).

Release during disposal

Waste generated during the industrial use scenario is generally recycled into the process, put into landfill or incinerated. Emissions from this kind of waste generation are assumed to be included in the release estimates of the TGD for the corresponding life-cycle step.

The discussion on emission at disposal for EPS in Section 2.3.1.4 is also relevant for XPS.

2.3.3 HIPS

2.3.3.1 Releases into working environment

Release during industrial use

There are few direct measurements associated with the industrial use of high impact polystyrene (HIPS). The mixing processes used are comparable to those used for the preparation of EPS and XPS. Following the approach of the RAR (EC 2008a) it is assumed that inhalation exposure of HBCDD during preparation of HIPS would be the same as for EPS.

For dermal exposure, there is no measured data and EASE was therefore used by in the RAR to assess exposure levels during industrial use of HBCDD as an additive. The same process was followed as for Masterbatch resulting in figures of 17 mg/day and 1.7 mg/day as reasonable worst cases for HIPS production with powder and granules, respectively.

Release during professional and private use
There is insufficient information regarding exposure to HBCDD from handling products made from HIPS. Handling HIPS containing HBCDD during assembly of electrical equipment is likely to be limited and result in much lower exposure levels than the scenarios arising during production of HIPS.

Release during service life
Handling HIPS containing HBCDD during service and repair of electrical equipment is likely to result in much lower exposure levels than the scenarios arising during production of HIPS.

Any exposure to HBCDD from products made from HIPS during normal service life is likely to be low and very occasional as dust generation is unlikely and the vapour pressure of HBCDD is low.

Release during disposal
The removal of electrical equipment from premises for disposal and the transport of electrical equipment to recycling or waste disposal sites are unlikely to cause any significant occupational or consumer exposure to HBCDD. Occupational exposures to HBCDD at managed landfill sites and managed incinerators are likely to be very low. Recycling of electrical equipment is unlikely to generate significant amounts of dust and it is expected that occupational exposure levels will be low. Julander et al (2005), for example, measured concentrations of polybrominated diphenyl ether (the most abundant brominated fire retardant present) of much less than 1µgm^{-3} in a recycling plant.

2.3.3.2 Release into environment

Release during industrial use
The emission estimates shown in Table 2.20 have been taken from the RAR and were derived using the approach in the OECD Emission Scenario Document on Plastics Additives (OECD, 2004). They are based on 2000-2004 production data and related to the EU15. The limited more recent information on the amounts of HBCDD used in HIPS indicate a similar amount to that in the risk assessment, and so the figures are not changed.

Table 2.20: Total, regional and continental emissions of HBCDD from industrial use of HIPS compound in the manufacture of flame retarded HIPS (Point sources)

HBCDD emissions	Total (kg/year)	Regional (kg/year)	Continental (kg/year)
Air	6.3	0.63	5.7
Wastewater	5.0	0.5	4.5
Surface water	1.3	0.13	1.2

Release during professional and private use
HBCDD is used as a flame retardant in high impact polystyrene (HIPS) which is used in electrical and electronic parts (e.g. distribution boxes for electrical lines, video cassette and VCR housings).

No quantitative information is given in the RAR. This life cycle step involves the assembly of electrical and electronic equipment, and so appears unlikely to lead to significant emissions to the environment.

Release during service life
No quantitative information is given in the RAR. Emissions to air may occur in a similar way to those from EPS/XPS as described in the previous two sections. The quantity of HBCDD used for this purpose is around 2% of that used in EPS/XPS, and the likely lifetime of articles containing HIPS is shorter than those with EPS/XPS. Hence the emissions from the service life in HIPS can be considered to be negligible in comparison to those estimated in Section 2.3.2.2.

Release during disposal
Waste generated during the industrial use scenario is generally recycled into the process, put into landfill or incinerated. Emissions from this kind of waste generation are assumed to be included in the release estimates of the TGD for the corresponding life-cycle step.

Articles containing HIPS treated with HBCDD may be returned to the manufacturers under the requirements of the WEEE directive, which will increase the potential for recycling of the materials in these articles. No specific information relating to the possible emissions of HBCDD from such recycling has been located. Material which cannot be used in recycling will be disposed of to landfill or incineration. Other articles will be disposed of into municipal waste, and the eventual fate of this material will also be to landfill or incineration. The proportion which is disposed of by each route will depend on the Member State in which this occurs (no information on the geographical distribution has been located) – the overall figures (2006) for the EU-27 are 68% to landfill, 32% to incineration (Eurostat, 2008). For landfill, the risk assessment report (EC, 2008a) concludes that HBCDD has a very low mobility in soil, with strong sorption to organic matter. Hence is it very unlikely that HBCDD will be leached in significant quantities from landfills. The risk assessment considers that incineration leads to only very low levels of products such as brominated dioxins, and that operated correctly it is a suitable method for the disposal of HBCDD.

2.3.4 Textile coating

2.3.4.1 Releases into working environment

Release during industrial use
Searl and Robertson (2005) reported inhalation exposures to HBCDD in during the production of textile coatings in one plant. Laboratory staff were primarily exposed to HBCDD when making up liquid formulations. Micronised HBCDD powder was added to some, but not all, of the products and this was the most important source of exposure for production workers.

Measured personal exposure concentrations to HBCDD for laboratory staff and production workers are in Table 2.21.

Table 2.21: Personal exposure concentrations for workers involved in the preparation of textile coatings (Searl and Robertson, 2005)

Task	Duration (minutes)	Concentration of dust (mgm^{-3})		Concentration of HBCDD (mgm^{-3})	
		Respirable	**Inhalable**	**Respirable**	**Inhalable**
Laboratory staff	Mean (standard deviation)	0.26 (0.26)	0.85 (0.36)	0.09 (0.09)	0.23 (0.34)
	90th percentile	0.50	1.25	0.19	0.53
Production using HBCDD	Mean (standard deviation	0.75 (0.44)	9.23 (6.64)	0.12 (0.11)	1.35 (11.94)
	90th percentile	1.16	15.47	0.23	3.12

For dermal exposure, there is no measured data and EASE was therefore used in the RAR to assess exposure levels during industrial use of HBCDD as an additive, assuming dermal exposure depends on the form of HBCDD (fine, standard grade and granules) used in the production rather than the product. Dermal exposure to HBCDD when making textile coatings occurs principally during manual adding of the substance to the process. It was assumed that both hands and face are exposed in textile coating. This gives 120 mg/day as a reasonable worst case for texture coating production. Protective clothing was not rigorously worn in the plant surveyed (Searl and Robertson, 2005).

Only 15 to 20% of textiles are coated with HBCDD (Searl and Robertson, 2005) and it is likely therefore that exposure occurs at the above levels for <25% of time worked.

Release during professional and private use

Dermal exposure to HBCDD may occur during sewing textiles with latex back-coating containing HBCDD. Due to the low vapour pressure the release to air from products is assumed to be relatively low at room temperature, but the release may be larger because of a temporary rise in temperature or because of weathering and abrasion. The RAR estimated that the inhalation exposure concentration will be 0.5 mgm^{-3} and the total dermal dust exposure to HBCDD will be 840 mg/day. This exposure is likely to be intermittent as a result of the wide range of flame retardants used with textiles.

Release during service life

Several studies have demonstrated the presence of brominated fire retardants in household, office and vehicle dust (eg Stapleton et al., 2008, Takigami et al., 2008, Stuart et al. 2008). House dust is the most important source of exposure to brominated fire retardants for the general population (Lorber, 2008). The Polymer Research Centre at the University of Surrey and the Bolton Institute undertook studies to determine the release of flame-retardants from backcoated textiles (Thomas and Stevens, 2006). It was estimated that if a 10 kg child ate all the dust generated from the sofas in their home, the daily exposure would be 1.2 µg/kg/day by the RAR who considered this exposure insignificant. The RAR also calculated that the internal exposure from inhalation of HBCDD from house dust will be 1.5 µg/kg bwt/day, using the results from Thomas and Stevens (2006).

On the basis of measured concentrations of HBCDD in house dust, Abdallah Mohamed et al (2008) estimated that UK adults and toddlers are exposed to respectively, to 1.1 and 4.4 µg HBCD/day (ie 0.015 and 0.44 µg/kg/day) from ingesting house dust.

The extraction of HBCDD from fabric by simulating oral suckling or mouthing and aqueous phase dermal exposure was also investigated by Thomas and Stevens (2006). In the RAR, the average daily mouthing was estimated to be 30 µg/kg bwt/day if the back coated side is available and 3 µg/kg/day if it is not.

Textile on mattress ticking may be flame-retarded with HBCDD but there is no information on how common this could be. Individuals could be exposed by lying on such a mattress with bedding. This exposure is assumed to be via dermal route, with an uptake of 4 % of the external exposure. The exposure was estimated to be 0.01 µg/kg bwt/day (EC, 2008a). This exposure level was considered insignificant by the RAR.

Exposures during sewing and repair of textiles are likely to be similar in intensity to those described in the sewing scenario above, but occur only occasionally, perhaps once per year.

Release during disposal
There is little information currently available to fully assess exposure levels during disposal. The removal of curtains or furnishings by consumers may lead to a short term small exposure but this is a “one off” for each item and, given the 10 or 20 year projected lifetime, is too small to be significant.

Coated textiles form a relatively low proportion of HBCDD containing waste. It is understood that most goes to landfill or incineration. Swan et al (2004) and Krajewski *et al* (2002) reported personal exposures to inhalable dust on several landfill sites to be between 0.3 and 9.0 mgm^{-3}. It is inconceivable that that there will be measurable levels of HBCDD attributable to treated textiles in dusts on a mixed landfill site. Exposure to HBCDD from textiles at managed incinerator sites is likely to be similarly low.

2.3.4.2 Release into environment

Release during industrial use
The emission estimates shown in Tables 2.22 and 2.23 have been taken from the RAR and are based on site specific information, applying the largest emission factor from actual sites to the use quantity not covered by the specific information. These emissions estimates are based on the tonnages used in the period 2000-2004. For the geographical distribution of these uses see Section 2.2.1. They relate to the EU-15 countries.

Table 2.22: Total, regional and continental emissions of HBCDD from formulation of polymer dispersions for textiles (Point sources, RAR).

HBCDD emissions	Total (kg/year)	Regional (kg/year)	Continental (kg/year)
Air	6.8	2.3	4.5
Wastewater	220	74	146
Surface water	55	18	37

Table 2.23: Total, regional and continental emissions of HBCDD at sites involved in industrial use of textile back-coating (Point sources, RAR)

HBCDD emissions	Total (kg/year)	Regional (kg/year)	Continental (kg/year)
Air	0.64	0.32	0.32
Wastewater	5,653	2,826	2,826
Surface water	1,413	706.5	706.5

The more recent information on the amounts of HBCDD used in textile coatings indicates a decrease over the figures from 2000-2004, by 80% for the 2007 figures. Assuming that the emissions would decrease pro rata, the revised emissions would be as in Table 2.24 and 2.25.

Table 2.24: Total, regional and continental emissions of HBCDD from formulation of polymer dispersions for textiles (Point sources, 2007 figures).

HBCDD emissions	Total (kg/year)	Regional (kg/year)	Continental (kg/year)
Air	1.4	0.5	0.9
Wastewater	44	15	29
Surface water	11	3.6	7.4

Table 2.25: Total, regional and continental emissions of HBCDD at sites involved in industrial use of textile back-coating (Point sources, 2007 figures)

HBCDD emissions	Total (kg/year)	Regional (kg/year)	Continental (kg/year)
Air	0.12	0.06	0.06
Wastewater	1130	565	565
Surface water	283	141	141

Release during professional and private use
No quantitative information is given in the RAR.

Release during service life
The release estimates shown in Table 2.26 were developed using the results of wearing and leaching tests on aged samples of treated textiles

Table 2.26: Total, regional and continental emissions of HBCDD from textiles during service life (wearing the fabric) (Diffuse sources).

HBCDD emissions	Total (kg/year)	Regional (kg/year)	Continental (kg/year)
Air	0	0	0
Wastewater	107	27	80
Surface water	27	7	20

The estimates shown in Table 2.27 are derived using the methods for service life releases from indoor service for organic flame retardants in OECD (2004).

Table 2.27: Total, regional and continental emissions of HBCDD from washing of textiles (Diffuse sources).

HBCDD emissions	Total (kg/year)	Regional (kg/year)	Continental (kg/year)
Air	0	0	0
Wastewater	10.5	2.6	7.9
Surface water	0	0	0

These emissions are taken from the risk assessment report (EC, 2008a) and are based on the tonnages used in the period 2000-2004. For the geographical distribution of these uses see Section 2.2.1. Specific information on the geographical distribution has not been located. However, most of the use of these textiles is expected to be in those countries which have specific regulatory requirement for use of flame-retarded textiles, namely the UK and Ireland. Therefore most of the above emissions are expected to occur in those two countries.

The reduced figure for use in textiles leads to reduced emission estimates from the service life of textiles, as in Tables 2.28 and 2.29.

Table 2.28: Total, regional and continental emissions of HBCDD from textiles during service life (wearing the fabric) (Diffuse sources, 2007 figures).

HBCDD emissions	Total (kg/year)	Regional (kg/year)	Continental (kg/year)
Air	0	0	0
Wastewater	21.4	5.4	16
Surface water	5.4	1.4	4

Table 2.29: Total, regional and continental emissions of HBCDD from washing of textiles (Diffuse sources, 2007 figures).

HBCDD emissions	Total (kg/year)	Regional (kg/year)	Continental (kg/year)
Air	0	0	0
Wastewater	2.1	0.5	1.6
Surface water	0	0	0

Release during disposal

Waste generated during the industrial use scenario is generally recycled into the process, put into landfill or incinerated. Emissions from this kind of waste generation are assumed to be included in the release estimates of the TGD for the corresponding life-cycle step.

Disposal of used furniture containing treated textiles is most likely to occur to municipal waste, and through that to landfill or to incineration. As noted above, most of the use of these treated materials is likely to be in the UK and Ireland. In these countries the main route of disposal for municipal solid waste is landfill (86% in the UK, 100% in Ireland). The possible emissions of HBCDD from landfill and incineration are considered in Section 2.3.3.2, with the conclusion that such emissions are negligible.

2.3.5 Total emissions

Table 2.30 shows estimated total releases of HBCDD as estimated in the RAR as outlined above. These figures are based on an estimated EU wide consumption of HBCDD of 9618 tonnes/year compared with the HBCDD Industry Users' Group estimate of EU wide consumption in 2007 of 11,000 tonnes. Using the revised production and use figures for 2006/2007, the total emissions are as in Table 2.31.

Table 2.30: Estimated total releases of HBCDD from uses in the EU15

HBCDD emissions	Total (kg/year)	Regional (kg/year)	Continental (kg/year)
Air	508.4	67.4	441
Wastewater	6,251	2,998	3,253
Surface water	1,933	875	1,058

Table 2.31: Estimated total releases of HBCDD from uses in the EU27 (2006/7 figures)

HBCDD emissions	Total (kg/year)	Regional (kg/year)	Continental (kg/year)
Air	649	82	568
Wastewater	1553	669	884
Surface water	924	361	563

Note on uncertainty

The basis of the emission estimates for each step is indicated in the sections above. Most of the formulation and industrial use estimates make use of actual measured emissions at sites, applying the worst case values from these to the quantities not covered by the sites providing information. These can be considered to have a reasonable degree of reliability. Other estimates are based on generic emission factors from the plastics additives emission scenario document (OECD, 2004); these are less specific to the substance (although the selection of some factors involves considering the volatility of the substance) and so will have a higher degree of uncertainty. The emission estimates over the service life are considered to have the highest degree of uncertainty.

INFORMATION ON ALTERNATIVE SUBSTANCES AND TECHNIQUES

3.1 Identification of alternative substances and techniques

Manufacturers have identified certain requirements that should be met before substitution of HBCDD can be made (Scheifers, 2004). These requirements include:

- Equal or better flame retardance for the product/part
- Equal or better performance and physical properties for the product/part
- Less risk to environment and human health
- Cost
- Commercial availability

Different applications require different levels of flame retardancy, which results in a large number of flame retardants for each specific purposes. The alternatives listed below are unlikely to represent a comprehensive list but are intended to give an overview of what possible alternative to HBCDD may be available. There are other alternatives to HBCDD in different applications, however little information is available on their environmental and health hazards or their technical and economic feasibility. The alternative substances and techniques described below have largely been identified from previous reviews of the availability of alternatives to brominated fire retardants undertaken by regulatory authorities including KEMI (2006) and the Illinois Environmental Protection Agency (2007). Further information about the technical feasibility of suggested alternatives was obtained by visiting the websites of the manufacturers and suppliers of these products and relevant trade associations representing manufacturers of insulation products and plastics.

ALTERNATIVE FIRE RETARDANTS FOR USE IN HIPS, EPS AND XPS

3.1.1 Halogenated flame retardants in conjunction with Antimony Trioxide

As an alternative substance for use in HIPS, other halogenated flame retardants in connection with antimony trioxide (ATO) are available:

- Decabromodiphenylether/ATO
- Decabromodiphenylethane/ATO
- Ethylenebis(tetrabromo phthalimide)/ATO

3.1.2 Organic aryl phosphorous compounds

As an alternative substance for use in HIPS, organic aryl phosphorous compounds are available:

- Triphenyl phosphate
- Resorcinol bis (biphenyl phosphate)
- Bis phenol A bis (biphenyl phosphate)
- Diphenyl cresyl phosphate

ALTERNATIVE FIRE RETARDANTS FOR USE IN TEXTILE BACKINGS

3.1.3 Textile alternatives

For the use of HBCDD in textiles, alternative substances are commercially available. These are:

- chlorinated paraffins
- decabromodiphenylether (please see Section 3.1.1 above for details)
- ammonium polyphosphates

- reactive phosphorus constituents

ALTERNATIVES TO EPS AND XPS INSULATION

At present, no suitable flame retardant is available to replace HBCDD in XPS or EPS as the required loadings of alternative flame retardants impair the structure and properties of the finished product to the extent that is no longer suitable for use. There are however a number of alternative forms of insulation that can be used in place of XPS or EPS. These alternative insulation systems have different characteristics to XPS and EPS and may be less appropriate for some specific use scenarios or may incorporate different environmental issues such as increased energy costs during transportation.

3.1.4 Phenolic Foam and Phenolic Resins

Closed cell phenolic foam is available as an alternative technique to EPS/XPS for some insulation applications in the building and construction industry,. It has been used in the building industry for various applications such as roofing, cavity board, external wall board, and floor insulation. Phenolic resins are used to bind glass fibre, mineral wool, or shredded waste to make insulation products. Glass fibre is the most commonly used material, accounting for 88% of all phenolic insulation products. Phenol and formaldehyde are the raw materials used to make the phenolic resin monomer.

3.1.5 Polyurethane and Polyisocyanurate Products

Polyisocyanurate modified urethane foams are available ss an alternative technique to EPS/XPS for some insulation applications in the building and construction industry. They are used in a variety of construction applications, and are commonly referred to as “polyiso” products. Polyiso insulation products use the following flame retardant chemicals: tris monochloropropyl phosphate (TMCPP), tris chloroethyl phosphate (TCEP), and RB-79 (diol made from tetrabromo phthalic anhydride).

3.1.6 Mineral wools, other mineral products and cellulose fibre

Mineral wools including glasswool and rockwool and products such as gypsum board are widely used in building insulation. Cellulose fibres, commonly manufactured from recycled paper, are less widely used and must be treated with flame retardants and pesticides such as boron salts before use. These products may be used in insulation products as part of the following systems:

Thermal barriers

Reflective insulation systems are available as an alternative technique to EPS/XPS for some insulation applications in the building and construction. These insulation systems include foils, films, or papers that are fitted between studs, joists, and beams. Common reflective system materials include foil-faced paper, foil-faced polyethylene bubbles, foil-faced plastic film, and foil-faced cardboard. The resistance to heat flow depends on the heat flow direction, and this type of insulation is most effective in reducing downward heat flow. When using alternative building insulation materials, the necessary flame retardancy is often provided by use of a thermal barrier. Thermal barriers are fire resistant coverings or coatings that separate the insulation material from the building interior. Thermal barriers can be used to increase the fire retardant performance for various types of insulation. Commonly used thermal barriers include: gypsum board, gypsum or cement plasters, perlite board, spray-applied cellulose, mineral fibre, or gypsum coatings, and select plywoods.

Loose-fill insulation
Loose-fill insulation that can be blown into place or be spray-applied by special equipment can be used as an alternative to EPS?XPS in some building and construction applications. It is particularly suited for filling existing wall cavities and for irregularly shaped areas. Materials used for blown-in or spray-applied insulation include rock wool, fibre glass, cellulose, or polyurethane foam. Loose-fill cellulose insulation is commonly manufactured from recycled newsprint, cardboard, or other forms of waste paper. The blown-in loose-fill insulation can provide additional resistance to air infiltration if the insulation is sufficiently dense. Loose-fill insulation can also be poured in place by using materials such as vermiculite or perlite. These materials are produced by expanding naturally occurring minerals in a furnace.

Blanket insulation
As an alternative to EPS/XPS in certain insulation applications in the building and construction industry, blanket insulation is available. It is usually made of fibre glass or rock wool and can be fitted between studs, joists, and beams. They are available in widths suited to standard spacings between wall studs or floor joists. Continuous rolls can be hand cut and trimmed to fit various spaces. The blankets are available with or without vapour retardant facings. Batts with special flame resistant facing are available where the insulation will be left exposed.

3.1.7 Intumescent systems

An intumescent system is a combination of various compounds that in the event of fire react together as a result of the temperature increase to form a carbon foam. This foam attains a thickness of 10 to 100 times of the originally applied coating and insulates the substrate material through its low thermal conductivity.

Intumescent systems include use of expanded graphite impregnated foams, surface treatments and barrier technologies of polymer materials.

Almost all intumescent systems comprise, in general, of three basic components
- a dehydrating component, such as APP
- a charring component, such as pentaerythritol (PER)
- a gas source, often a nitrogen component such as melamine

Whatever the detailed mechanisms for intumescents systems are, the formation of a thick char layer, high carbon concentration, high viscosity of pyrolyzing melt and low penetration capability for propagation of heat, makes intumescent systems efficient to reduce flammability and the exposure of fume gases (Swaraj 2001), (Posner 2004).

ALTERNATIVES TO HIPS

3.1.8 Polyethylene with Magnesium Hydroxide

As an alternative technique to flame-retarded HIPS, it is possible to use polyethylene in conjunction with magnesium hydroxide.

3.2 Information on alternatives

3.2.1 Human health and environmental effects

ALTERNATIVE FIRE RETARDANTS FOR USE IN HIPS, EPS AND XPS

3.2.1.1 Halogenated flame retardants in conjunction with Antimony Trioxide

Human health effects

Antimony Trioxide

Antimony trioxide has an oral LD50 in rats of >34,600 mg/kg and LD50 values for administration by intraperitoneal and subcutaneous injection are 3,250 and 7,904 mg/kg respectively (RTECS). The lowest reported toxic dose in repeated dose experiments listed in RTECS are summarised in Table 3.1.

Table 3.1 Lowest reported toxic dose of antimony trioxide in repeated dose experiments

Species	Duration of experiment	Exposure Route	Dose	Effects
Rat	90 days	Oral	1690 mg/kg/day	Liver - changes in liver weight Blood - other changes Biochemical - Enzyme inhibition, induction, or change in blood or tissue levels - phosphatases
Rat	21 days	oral	1000 mg/kg/day	Nutritional and Gross Metabolic - weight loss or decreased weight gain
Rat	17 weeks	Inhalation	72 ugm^{-3} (24 hours/day)	Blood - pigmented or nucleated red blood cells Biochemical - Enzyme inhibition, induction, or change in blood or tissue levels - true cholinesterase Biochemical - Metabolism (Intermediary) - lipids including transport
Rat	1 year	Inhalation	4.5 mgm^{-3} (6 hours/day)	Sense Organs and Special Senses (Eye) - effect, not otherwise specified Lungs, Thorax, or Respiration - other changes
Rat	20 days	Inhalation	2.6 mgm^{-3} (6 hours/day)	Lungs, Thorax, or Respiration - other changes Lungs, Thorax, or Respiration - changes in lung weight
Rat	13 weeks	Subcutaneous	282 mg/kg/day	Cardiac – other changes
Guinea pig	10 weeks	Inhalation	45 mgm^{-3}	Lungs, Thorax, or Respiration - fibrosis, focal (pneumoconiosis) Liver - fatty liver degeneration Related to Chronic Data - death

In one year inhalation studies in rats, lung tumours have been reported in animals exposed at concentrations ranging between 1.6 and 50 mgm^{-3} (RTECS). Data from animal experiments seem to indicate that females are more sensitive concerning developing lung neoplasms than males. Antimony trioxide induced DNA damage in bacteria (IARC, 1989).

In experiments in pregnant rats, inhalation exposure to antinomy oxide at concentrations of 82 and 270 ugm^{-3} throughout gestation have given rise to post-implantation mortality and foetal toxicity (RTECS).

There are epidemiological indications that antimony trioxide causes dermatitis and has an impact on reproduction in female workers (IARC, 1989).

Antimony trioxide is classified in the EU as "Harmful (Xn)" and must be labelled with the risk-phrase "Possible risk of irreversible effects" (R40) as a possible carcinogen.

The UK Workplace Exposure Limit for antimony and its inorganic compounds is 0.5 mgm^{-3}.

Name of substance	Antimony Trioxide	
Abbreviation		
CAS No.	8452-53-9	
Endpoint	Value	Reference
LD50 rat oral	>34600 mg/kg	RTECS
NOAEL mg/kg bw		
Reproductive toxicity Foetal toxicity and post-implantation mortality, LOEL rat inhalation	82 ugm^{-3}	RTECS
Repeated dose Toxicity, LOAEL Rat oral Rat inhalation	 1000 mg/kg/day 72 ugm^{-3} (24 hour exposure)	RTECS
Genotoxicity		
Carcinogenicity LOEL rat inhalation	Possible human carcinogen 1.6 mgm^{-3}	IARC
Critical endpoint	Effects on general health (oral exposure) LOEL Lung cancer LOEL in rats OEL	1000 mg/kg/day 1.6 mgm^{-3} 0.5 mgm^{-3}
Preliminary DNEL	DNEL for critical endpoint	Remarks
Workers, oral	50 mg/day	Intake equivalent to workplace exposure limit
General population, oral	0.25 mg/day	Intake equivalent to inhalation DNEL
Workers, inhalation	0.5 mgm^{-3}	Workplace exposure limit
General population, inhalation	0.0025 mgm^{-3}	Default assessment factor for worker/general population exposure, adjustment to allow for difference in duration of exposure (x10 for lifetime exposure) Based on workplace exposure limit

Decabromodiphenylether/ATO

Studies of toxicokinetics of Decabromodiphenyl ether (decaBDE) reveal that the chemical can be absorbed by the oral route to a limited extent, does not accumulate in tissues, and undergoes clearance, largely as a result of metabolism in the liver and excretion in the bile.

Short-term and subchronic studies demonstrated low toxicity from oral exposure to decaBDE with NOAELs of 3,000 mg/kg-day or higher. NTP (1986) conducted a chronic toxicity and carcinogenicity dietary study in F344 rats. DecaBDE caused an increase in the incidence of thrombosis in the liver in high-dose male rats (2,240 mg/kg-day). A dose-dependent, but insignificant, increase in the incidence of degeneration of the liver was also observed in treated male rats. In the spleen, a dose-dependent increase (statistically significant in the high-dose group) in the incidence of fibrosis was observed in males. In the mandibular lymph node, lymphoid hyperplasia increased in males in a dose-dependent manner, but the incidence reached statistical significance only at the high dose. Histopathology examination also revealed a dose-dependent increase in the incidence of neoplastic nodules in the liver in both male and female rats. Female rats appeared to be refractory to the systemic toxicity of decaBDE at the doses used in this study.

The observed toxicity of decaBDE in the 2-year study in rats is further supported by the 2-year mouse study conducted by NTP (1986). Significant increases in the incidence of centrilobular hypertrophy were observed in the liver of treated male mice. In the thyroid gland, a dose-dependent and statistically significant increase (at all dose levels) in the incidence of follicular cell hyperplasia was observed in male mice. In the females, the incidence increased in the low- and high-dose groups compared with the control group, but the increase was not statistically significant at any dose level. Female mice in the high-dose group exhibited a significant increase in the incidence of stomach ulcers. In addition, there were significant increases in the combined incidence of hepatocellular adenomas or carcinomas at both low and high doses in male mice. In the thyroid gland, follicular cell adenomas or carcinomas (combined) were slightly, but not significantly, increased in treated mice of both sexes. Similar to female rats, female mice appeared to be refractory to the systemic toxicity of decaBDE.

DecaBDE also has been shown to induce behavioural changes in several studies in mice and rats (Viberg et al., 2007, 2003a; Rice et al., 2007). In the principal study selected, Viberg et al. (2003a) investigated the neurotoxic effects of decaBDE on spontaneous motor behaviour of adult NMRI male mice when these animals were exposed to a single oral dose as neonates on PND 3, 10, or 19 (i.e., at different stages of neonatal mouse brain development). Pair-wise testing between adult mice exposed on PND 3 and control groups indicated significant dose-related changes in all three spontaneous behaviour variables at 2, 4, and 6 months of age. Adult mice exposed neonatally up to 20.1 mg on either PND 10 or 19 did not show any significant differences in any of the variables. These data suggested that there was a critical window for the induction of behavioural disturbances, and the neurotoxic effect of neonatal decaBDE exposure was persistent and also worsened with age in male mice.

The appropriate hazard descriptor for decaBDE is ‘suggestive evidence of carcinogenic potential’ (U.S. EPA, 2005a, b). DecaBDE was not mutagenic or genotoxic in several in vitro studies. In the International Agency for Research and Cancer (IARC, 1990) evaluation, it was concluded there was limited evidence for the carcinogenicity of decaBDE in experimental animal and classified it as Group 3: "Not classifiable as to its carcinogenicity to humans". In the EU RAR for DecaBDE, a cautious approach was followed, and a LOAEL for carcinogenicity of 1,120 mg/kg/day was stated based on the increased incidence of liver neoplastic nodules from the lowest tested dose (1,120 mg/kg/day).

Name of substance	Decabromodiphenylether	
Abbreviation	DecaBDE	
CAS No.	1163-19-5	
Endpoint	Value	Reference
LD50 (rat, oral)	2000 mg/kg	RTECS
NOAEL mg/kg bw		
Reproductive toxicity Effects on neurobehavioural development	20.1 mg/kg/day	Viberg et al (2007)
Repeated dose Toxicity, LOAEL in male rats	2,240 mg/kg-day	
Genotoxicity		
Carcinogenicity	LOAEL for carcinogenicity of 1,120 mg/kg/day in animals "not classifiable in humans"	RAR IARC, 1990
Critical endpoint	Effects on neurobehavioural development	Dose 20.1 mg/kg/day
Preliminary DNEL	DNEL for critical endpoint	Remarks
Workers, oral	5.6 mg/day	Default assessment factors plus x5 for LOEL rather than NOEL
General population, oral	2.8 mg/day	
Workers, inhalation	0.56 mgm^{-3}	
General population, inhalation	0.07 mgm^{-3}	

Decabromodiphenylethane/ATO

Ethane, 1,2-bis(pentabromophenyl) (EBP; CAS no. 8452-53-9) dose levels of 0, 100, 320 and 1000 mg/kg/day administered to rats by gavage in corn oil for 90 consecutive days produced no compound-related clinical signs of systemic toxicity, ocular lesions, or alterations in urinalysis, clinical chemistry, and haematology values in the treated or recovery groups. No biologically or toxicologically significant differences were observed in body weights, body weight gains, and food consumption. Statistically significant differences were found between control and high-dose animals in mean absolute or relative liver weights. Histomorphological evaluation showed in male rats low-grade liver changes consisting of minimal to slight hepatocellular vacuolation (high-dose males) and minimal to slight centrilobular hepatocytomegaly (high- and possibly mid-dose males). These changes had resolved by the end of the 28-day recovery period. No treatment-related changes were found in the livers of female rats. No treatment-related histomorphologic changes were present in any of the other tissues examined in either sex, except for evidence of aspirated test article in individual rats. The 90-day EBP NOAEL in the rat was ≥1000 mg/kg/day, and was consistent with that of the preceding 28-day study (no-effect level ≥1250 mg/kg/day). EBP's lack of toxicity is likely related to poor bioavailability due to its high molecular weight and low solubility (Hardy, 2002).

Name of substance	Ethane, 1,2-bis(pentabromophenyl)	
Abbreviation	DecaBDEthane	
CAS No.	8452-53-9	
Endpoint	Value	Reference
LD50	No information	
NOAEL mg/kg bw	No information	
Reproductive toxicity	No information	
Repeated dose Toxicity, NOAEL rat	≥1000 mg/kg bw	Hardy, 2002
Genotoxicity	No information	
Carcinogenicity	No information	
Critical endpoint	Not known	
Preliminary DNEL	DNEL for critical endpoint	Remarks
Workers, oral	700 mg/day	Default assessment factors Based on NOEL in repeated dose experiments
General population, oral	350 mg/day	
Workers, inhalation	70 mgm^{-3}	
General population, inhalation	17.5 mgm^{-3}	

Ethylenebis(tetrabromo phthalimide)/ATO

The information in this section is taken from the HPV Data Summary and Test Plan for 1H-Isoindole-1,3(2H)-dione, 2,2’-(1,2-ethanediyl)bis(4,5,6,7-terabromo-) (a.k.a. Ethylene bis tetrabromophthalimide) prepared by Abermarle (2004).

In studies of uptake and elimination, Ethylenebis(tetrabromophthalimide) (EBTBP) was mainly excreted in the faeces (65% of dose), urine (15% of dose), and breath (1% of dose) twenty-four hours after oral dosing in laboratory rats. The organs containing the highest concentrations of the compound were the liver, kidney, and muscles. Lower levels were detected in the brain and fat.

The acute oral LD_{50} in the rat was greater than 7.5 g/kg. The dermal LD50 in rabbits was > 2,000 mg/kg and the inhalation LC50 in rats was > 203 mg/L for 1 hour.

No dermal irritation or reactivity was observed in rabbits treated with 0.5 g or 2.0 g/kg ethylenebis(tetrabromophthalimide). Ethylenebis(tetrabromophthalimide) was determined to be an eye irritant when tested in rabbits at a dose of 100 mg/eye. It was mildly toxic to rats when inhaled.

Repeated Dose Toxicity: In a 28-day experiments in rats EBTBP was fed to male rats (n=10/group) at 0, 0.01, 0.1 and 1% of the diet for 28 days. No mortality occurred during the study. No clinical signs of toxicity were observed. Mean body weights, body weight gains, food consumption and organ weights, haematology and serum chemistry parameters were not affected by treatment. No gross or microscopic lesions attributable to test article were detected at necropsy or on light microscopy. The 28-day NOEL was ∞ 1% of the diet. This is estimated to be ~ 1,000 mg/kg/ ay.

In a 90-Day study in rats EBTBP was administered to four groups of rats (n=15/sex/group) at 0, 0.01, 0.1 and 1.0% of the diet for 90 days followed by 46 days during which the rats were fed control diet. No changes in haematology or serum chemistry values related to treatment were detected on study days 0, 45, 92. No effect of treatment was found on urinalysis (d 0, 45 and 90). The mean relative and absolute organ weights of the liver, kidney, heart, and thyroids from the control and 1.0% groups were statistically comparable. Several animals died on test from non-test article related causes (most deaths were related to collection of blood for haematology and serum chemistry evaluations). Gross necropsy from animals dieing on test and sacrificed on days 92, 134, 135 and 136 revealed no test article-related gross lesions. No test article related lesions were detected on histopathology. The 90-day NOEL was 1% of the diet. This was estimated to be ~ 1,000 mg/kg/day.

Developmental: EBTBP was administered to four groups of 25 pregnant rats by gavage in corn oil at doses of 0, 100, 500 or 1000 mg/kg/d on gestation days 6-15. No maternal mortality or clinical signs of toxicity were observed during the study. No treatment-related differences were noted among the groups with respect to maternal body weights, food consumption, necropsy or caesarean section data. No treatment-induced fetal malformations or developmental variations were detected. The maternal and foetal NOEL was 1,000 mg/kg/day.

EBTBP was administered to two groups of 20 pregnant rabbits each by gavage in methyl cellulose at dose of 0 or 1,000 mg/kg/d on gestation days 7-19. No maternal mortality, abortions or clinical signs of toxicity were observed during the study. Maternal body weights, weight gain, food consumption, necropsy observations and cesarean section data were generally comparable among the groups. No treatment-related malformations or developmental variations were observed. The maternal and foetal NOEL was 1,000 mg/kg/day.

Genetic Toxicity - Mutagenicity

In the Ames assay, the tester strains used were Salmonella TA98, TA100, TA1535, TA1537, and TA1538 and E. coli, WP2 uvrA. Each strain was tested with and without a source of exogenous metabolic activation of Arochlor-induced rat liver microsomes. EBTBP dose levels were 0, 1, 10, 100, 500, 1,000 and 5,000 ug/plate. Positive and negative controls were included, and performed as expected. No increase in revertant colonies was found at any EBTBP dose level either in the presence or absence of microsomal enzymes. EBTBP was not genetically active in this assay. (Mutagenicity Evaluation of Ethylene-1,2-bis(3,4,5,6-tetrabromophthalimie) in the Ames Salmonella/Microsome Assay. February 18, 1982. Chemical Inspection & Testing Institute, Japan, Induced Mutation Division).

Name of substance	Ethylenebis(tetrabromo phthalimide)	
Abbreviation	EBTBP	
CAS No.	32588-76-4	
Endpoint	Value	Reference
LD50 – rat oral	>750 mg/kg	HPV data summary (2004)
NOAEL mg/kg bw		
Reproductive toxicity	No reported effects on fertility or foetal development; NOEL 1000 mg/kg/day	HPV data summary (2004)
Repeated dose Toxicity, NOAEL rat, 90 day oral	1000 mg/kg	HPV data summary (2004)
Genotoxicity	Not genotoxic	HPV data summary (2004)
Carcinogenicity	No information	
Critical endpoint	Not determined	
Preliminary DNEL	DNEL for critical endpoint	Remarks
Workers, oral	700 mg/day	Default assessment factors Based on NOEL in repeated dose experiments
General population, oral	350 mg/day	
Workers, inhalation	70 mgm^{-3}	
General population, inhalation	17.5 mgm^{-3}	

Environmental effects

Diantimony trioxide

Identity and properties

CAS number	1309-64-4
Water solubility	2.76 mg/l in reconstituted water (=ISO 6341 medium) at 22°C (EC, 2008)
Vapour pressure	133 Pa (1 mm Hg) at 574°C (EC, 2008)
Log Kow	Not relevant for this type of substance

Fate data

Biodegradability	Not readily biodegradable (EC, 2008).
Bioconcentration factor	Bioaccumulation potential seems to be low to moderate* (EC, 2008).

* No reliable bioaccumulation studies are available. Measured data from different aquatic organisms have been used to calculate tentative BCF values which range from <5 – 15,000. It should be noted that there is considerable uncertainty in these values (EC, 2008).

Aquatic effects

Species	Effect	Value	Reference
Marine fish (*Pargus major*)	96 hr LC_{50}	6.9 mg Sb/l[#]	EC, 2008
Freshwater fish (*Pimephales promelas*)	96 hr LC_{50}	14.4 mg Sb/l	EC, 2008
Freshwater fish (*Pimephales promelas*)	28 d NOEC/LOEC (growth; length)	1.13/2.31 mg Sb/l	EC, 2008
Invertebrate (*Chlorohydra viridissimus*)	96 hr LC_{50}	1.77 mg Sb/l	EC, 2008
Invertebrate (*Daphnia magna*)	21 d NOEC/LOEC (reproduction)	1.74/3.13 mg Sb/l	EC, 2008
Algae (*Raphidocelis subcapitata*)	72 hr E_rC_{50} (growth rate) 72 hr NOEC/LOEC (growth rate)	> 36.6 mg Sb/l 2.11/4.00 mg Sb/l	EC, 2008

The PNEC for freshwater aquatic organisms based on the above data is 0.113 mg Sb/l, derived by applying an assessment factor of 10 to the lowest NOEC for freshwater fish (EC, 2008b).

[#] This was the only reliable study for marine aquatic organisms. Therefore the PNEC for marine water had to be derived by applying an assessment factor of 100 to the lowest NOEC for freshwater fish; $PNEC_{\text{marine water}}$ 11.3 µg Sb/l (EC, 2008).

There is currently no agreed approach to perform a PBT-assessment of a metal; therefore a PBT-assessment has not been performed. Diantimony trioxide is classified as a dangerous substance and is listed in Annex 1 of Directive 67/548/EEC.

Given that the ESR process involved a rigorous data searching and review process, with the possibility of the generation of new data through tests, the values reported in the RAR for diantimony trioxide can be considered to have little uncertainty.

The vapour pressure of diantimony trioxide at ambient temperature is considered to be negligible. In the environment, antimony trioxide will slowly dissolve and transform into $Sb(OH)_3$, which is oxidised to $Sb(OH)_6^-$ under oxic conditions. Antimony, being a natural element cannot by definition be degraded. However, it can be transformed between different speciation forms and oxidation states.

Decabromodiphenylether

Identity and properties

CAS number	1163-19-5
Water solubility	<0.1 μg/l at 25°C (EC, 2002)
Vapour pressure	4.63×10^{-6} Pa at 21°C (EC, 2002)
Log Kow	6.27 (measured value) (EC, 2002))

Fate data

Biodegradability	Not readily biodegradable (EC, 2002).
Bioconcentration factor	Appears to have a low bioaccumulation potential, although there is a lack of consistent evidence (ECB, 2007).

Aquatic effects

Species	Effect	Value	Reference
Fish (*Oryzias latipes*)	48 hr LC_{50}	>500 mg/l (well in excess of substance's solubility).	EC, 2002
Fish (*Oncorhynchus mykiss*)	120 day feeding experiment (dose of 7.5-10 mg/kg bw/day)	Increased liver weights and lactate levels in blood after 120 days. Significance of these effects unknown.	EC, 2002
Invertebrates (*Daphnia magna*)	21 d NOEC	No information for deca-. Study carried out for octa-. No effects on survival, growth or reproduction up to 2 μg/l.	EC, 2002
Algae (*Skeletonema costatum and Thalassiosira pseudonona*) *Chlorella* sp.	72 hr E_rC_{50} 96 hr E_rC_{50}	At the highest concentration tested (1mg/l), growth reduced by <50%. Not clear if any toxic effects were seen. EC_{50} cannot be determined.	EC, 2002

It is not possible to derive a true PNEC for the aquatic compartment as no effects are expected at concentrations up to the water solubility of decabromodiphenylether.

A tentative PNEC of >1 μg/l can be estimated based on an EC_{50} >1 mg/l from the algal studies, using an assessment factor of 1,000. Alternatively, a tentative PNEC of >0.2 μg/l can be derived based on the 21 d NOEC for *Daphnia magna* with octabromo-diphenylether (no effects were seen up to the solubility limit of 2 μg /l). This approach assumes that deca- has a similar toxicity to octa- in long-term tests and the derived PNEC is of the same order of magnitude as that estimated using the algal data(EC, 2002).

Given that the ESR process involved a rigorous data searching and review process, with the possibility of the generation of new data through tests, the values reported in the RAR for decabromodiphenylether can be considered to have little uncertainty.

Decabromodiphenylether is persistent. No significant toxicity has been observed. A conclusion on bioaccumulation cannot be drawn based on the current evidence (ECB, 2007). This substance is not currently classified for environmental or health effects according to Directive 67/548/EEC.

Relative emissions: the emissions of HBCDD from industrial use in HIPS are related to the vapour pressure. Decabromodiphenylether has a lower vapour pressure and so emissions from the same processes would be expected to be lower. Losses of HBCDD from articles during their service life are also related to the vapour pressure; hence emissions from service life would be expected to be lower. Decabromodiphenylether is not readily biodegradable, so is not expected to be degraded significantly in wastewater treatment plants (wwtps) or to degrade in the environment.

The emission estimates for HBCDD from use in textiles are based largely on specific measurements. Therefore it is not appropriate to make an estimate of the relative emissions for decabromodiphenylether based on a comparison of the physico-chemical properties.

Decabromodiphenylether is used in HIPS and in flame retarded textile coatings (EC, 2002).

Decabromodiphenylethane

Identity and properties

CAS number	84852-53-9
Water solubility	~ 0.72 µg /l at 25°C (measured value) (EA, 2007)#
Vapour pressure	~ 1×10^{-6} Pa at 25°C (nominal value to indicate low volatility) (EA, 2007)
Log Kow	No value selected (a more reliable measurement is needed) (EA, 2007)

There is evidence from predictive models and analogues that the true water solubility of this substance could be much lower (EA, 2007).

Fate data

Biodegradability	Not readily biodegradable (EA, 2007).
Bioconcentration factor	25 l/kg (limit value used in calculations for the assessment for illustrative purposes) (EA, 2007).

Aquatic effects

Species	Effect	Value	Reference
Fish (*Oncorhynchus mykiss*)	96 hr LC_{50}	No effects seen at the highest loading rate of 110 mg/l*.	EA, 2007
Fish (*Cyprinus carpio*)	8 wk bioaccumulation study	No abnormalities observed at exposure concentrations of 0.5 and 0.05 mg/l.	EA, 2007
Invertebrates (*Daphnia magna*)	48 hr EC_{50}	No effects seen at the highest loading rate of 110 mg/l*.	EA, 2007
Algae (*Selenastrum capricornutum*)	96 hr EC_{50}	No effects seen at the highest loading rate of 110 mg/l*.	EA, 2007

* Given the excess of substance used to prepare the WAF in these studies, it is assumed that the water solubility limit of ~ 0.72 µg/l at 25°C was reached.

No toxic effects were seen in any of the tests with fish, invertebrates or algae. Therefore, it is not possible to derive a PNEC for aquatic organisms (freshwater or marine).

Based on screening information only, decabromodiphenylethane is considered to be potentially persistent. A firm conclusion on bioaccumulation potential cannot be drawn due to the lack of reliable data. The substance does not meet the toxicity criterion. Decabromodiphenylethane is not classified for either environmental or human health hazards on Annex 1 of Directive 667/548/EEC (EA, 2007).

Relative emissions: the emissions of HBCDD from industrial use in HIPS are related to the vapour pressure. A vapour pressure of 1×10^{-6} Pa at 25°C was assumed in the risk assessment for decabromodiphenylethane to indicate low volatility. However, the vapour pressure of this substance could be even lower. Therefore emissions from the same processes would be expected to be lower than for HBCDD. Losses of HBCDD from articles during their service life are also related to the vapour pressure; hence emissions from service life would be expected to be lower. Decabromodiphenylethane is not readily biodegradable, so is not expected to be degraded significantly in wwtps or to degrade in the environment.

Ethylene bis(tetrabromophthalimide)

Identity and properties

CAS number	32588-76-4
Water solubility	<1.63 mg/l (measured), 3×10^{-9} mg/l (calc) – from ECB (2008)
Vapour pressure	3.3×10^{-20} Pa (calc)(ECB, 2008)
Log Kow	9.8 (calc) (ECB, 20082)

Fate data

Biodegradability	Not readily biodegradable (ECB, 2008).
Bioconcentration factor	Does not meet the B criterion based on indicators of low bioaccumulation potential (ECB, 2008).

Aquatic effects

Species	Effect	Value	Reference
Fish (*Oryzias latipes*)	48 hr LC_{50}	>500 mg/l (well in excess of substance's solubility).	ECB, 2008

The EU PBT Working Group (2008)_ concluded that it is not possible to derive a true PNEC for the aquatic compartment as no effects are expected at concentrations up to the water solubility. Although the data can be considered reliable, they are insufficient to derive a PNEC, and so there is uncertainty over what level should be used to assess exposures.

The PBT Working Group concluded that the substance meets the P/vP criteria, does not meet the B criterion based on indicators of limited bioaccumulation, and does not meet the T criterion in mammals. According to the ESIS database, this substance is not classified in the Annex I of Directive 67/548/EEC as such, but it may be included in one of the group entries.

Relative emissions: the emissions of HBCDD from industrial use in HIPS are related to the vapour pressure. The substance has a very much lower estimated vapour pressure and so emissions from the same processes would be expected to be lower. Losses of HBCDD from articles during their service life are also related to the vapour pressure; hence emissions from service life would be expected to be lower. Ethylene bis(tetrabromophthalimide) is not readily biodegradable, so is not expected to be degraded significantly in wwtps or to degrade in the environment.

3.2.1.2 Organic aryl phosphorous compounds

Health effects

Triphenyl phosphate

The information in this section is drawn from the SIDS (UNEP, 2002).

Acute toxicity data exist for several species of animals and indicate low toxicity via the oral and dermal routes (1320 to 10 800 mg/kg and >7900 mg/kg, respectively). No inhalation data are available. TPP also exhibits low toxicity in short-term studies and is not an irritant to mouse skin. In repeated dose experiments in rats, reduced body weights and an increase in liver weights were observed in a 35 day experiment at an oral dose of 350 mg/kg/day with an estimated NOEL of 70 mg/kg. In two 4 month studies, the NOEL for effects on weight was estimated as 161 mg/kg.

There are limited data that suggest an absence of genotoxic activity and no indication of carcinogenic potential was observed in the mouse lung ademona assay.

No effects on fertility or foetal development were observed following repeated dietary exposure of 166-690 mg/kg per day for a period of 91 days, including mating and gestation periods.

The neurotoxicity of TPP has been debated since the early studies of Smith et al. (1930, 1932), which reported delayed neuropathy in cats and monkeys exposed to TPP in acute and short-term studies. However, Wills et al. (1979) could demonstrate no ataxia or neuropathic damage in cats exposed to 99.9%-pure TPP. Consequently, the validity of the Smith studies has been questioned. Other toxicity studies using behavioural and morphological end-points have demonstrated that TPP administered short-term to cats and chickens fails to produce neuro-toxic changes. A mixture of triaryl (including cresyl and phenyl) phosphates produced neurochemical changes and minor peripheral nerve pathology in the caudal nerve of rats; acute intraperitoneal injection of 150 mg or less produced neither biochemical nor morphological change. It has been suggested that small concentrations of impurities may explain the neurotoxic effects observed in some studies.

Name of substance	Triphenyl phosphate	
Abbreviation	TPP	
CAS No.	115-86-6	
Endpoint	Value	Reference
LD_{50} mouse oral	1320 mg/kg	SIDS (2002)
NOAEL mg/kg bw		
Reproductive toxicity	No effects on fertility or development have been observed	SIDS (2002)
Repeated dose Toxicity, NOAEL rat	161 mg/kg/day	SIDS (2002)
Genotoxicity	Limited evidence suggesting an absence of genotoxic activity	SIDS (2002)
Carcinogenicity	Limited evidence suggesting an absence of carcinogenic potential	SIDS (2002)
Critical endpoint	Liver toxicity	Dose: 161 mg/kg/day - NOEL
Preliminary DNEL	DNEL for critical endpoint	Remarks
Workers, oral	112.7 mg/day	Default assessment factors
General population, oral	56.35 mg/day	
Workers, inhalation	11.27 mgm^{-3}	
General population, inhalation	2.82 mgm^{-3}	

Resorcinol bis (biphenyl phosphate)

The Illinois Environmental Protection Agency (2007) provided a summary of the toxicology of resorcinol bis (biphenyl phosphate) in a report on alternatives to decaBDE. Their findings are tabulated below:

Endpoint	Data
Chronic toxicity	28-day LOAEL for increased liver weight=100 mg/kg/d (lowest dose tested); NOAEL for immune system effects=5000 mg/kg/d (highest dose tested); no other short- or long-term data.
Irritation and sensitisation	Minimal skin and eye irritation; not a sensitizer
Mutagenicity	No cancer data; not mutagenic (1 assay); no chromosomal abnormalities (1 assay);
Reproductive/developmental effects	Rat 2-generation study NOAEL=20000 mg/kg/d (highest dose tested)

Limited additional data are listed by RTECS. The oral LD_{50} in rats is reported to be >5000 mg/kg. The LC_{50} is greater than 4860 mgm^{-3}. Exposure led to lowered activity levels and breathing difficulties. Lowered activity levels were also observed following dermal application to rats and the LD_{50} by this route is >2000 mg/kg.

RTECS also lists two additional repeated dose experiments. The lowest reported toxic dose by inhalation in rats is 500 mgm^{-3} (6 hours/day) in a four week experiment. Effects included changes in lung and liver weights. In a 28 day experiment in mice, the lowest reported toxic dose was 5000 mg/kg/day which was associated with metabolic changes.

Name of substance	resorcinol bis (biphenyl phosphate)	
Abbreviation	RBBPP	
CAS No.	57583-54-7	
Endpoint	Value	Reference
LD$_{50}$ rat oral	>5000 mg/kg	RTECS
NOAEL mg/kg bw		
Reproductive toxicity	No adverse effects reported on fertility or development at 20000 mg/kg/day	IEPA
Repeated dose Toxicity, LOAEL rat oral – increased liver weight rat inhalation	 100 mg/kg/day 500 mgm-3 (6 hours/day)	IEPA
Genotoxicity	Limited data suggest absence of genotoxicity	IEPA
Carcinogenicity	No data	IEPA
Critical endpoint		
Preliminary DNEL	DNEL for critical endpoint	Remarks
Workers, oral	9.3 mg/day	Default assessment factors plus x5 for LOEL rather than NOEL Based on oral LOEL in repeated dose experiments
General population, oral	4.7 mg/day	
Workers, inhalation	0.34 mgm^{-3}	Default assessment factors plus x5 for LOEL rather than NOEL Based on inhalation LOEL in repeated dose experiments
General population, inhalation	0.084 mgm^{-3}	

Bis phenol A bis (biphenyl phosphate) (BPA-BDPP) 5945-33-5

NICNAS (2000) summarise the limited available data that are available for this substance. It has a low toxicity following oral administration with the rat LD$_{50}$ being > 2000 mg/kg. The dermal LD$_{50}$ is also >2000 mg/kg. It does not cause irritation to the eyes or skin in experiments in rabbits and is non sensitising in an assay in guinea pigs.

There are no cancer data and the available data suggest an absence of genotoxicity.

In a 28-day experiment in rats the NOAEL was 1000 mg/kg/d (highest dose tested, includes neurotoxicity evaluation).

Name of substance	Bis phenol A bis (biphenyl phosphate)	
Abbreviation	BPA-BDPP	
CAS No.	5945-33-5	
Endpoint	Value	Reference
LD_{50} rat oral	>2000 mg/kg	NICNAS
NOAEL mg/kg bw		
Reproductive toxicity		
Repeated dose Toxicity, NOAEL rat	1000 mg/kg/day	NICNAS
Genotoxicity	Not genotoxic	NICNAS
Carcinogenicity	No information	
Critical endpoint	Not known	
Preliminary DNEL	DNEL for critical endpoint	Remarks
Workers, oral	467 mg/day	Default assessment factors Based on NOEL in repeated dose experiments
General population, oral	233 mg/day	
Workers, inhalation	46.7 mgm^{-3}	
General population, inhalation	11.7 mgm^{-3}	

Diphenyl cresyl phosphate

The following information is provided in the SIDS initial assessment profile (UENP, 1998).

Acute toxicity
Oral/Rat: LD_{50}: 6,400 mg/kg
Inhalation/Sheep: LC_{50}: > 0.37 mg/l/1h
Dermal/Rabbit: LD_{50}: > 5,000 mg/kg

Repeated dose toxicity
In an OECD Combined Repeated Dose and Reproductive/Developmental Screening Toxicity Test in rats, salivation, reduced body weight gain and increased water intake were observed in both sexes, and increased food consumption was observed in male rats at 300 mg/kg/day. This was combined with enlargement and cortical vacuolation of the adrenals, enlargement of the liver, and fatty change of the proximal tubular epithelium were found in both sexes. In addition, reduction of fatty change of the hepatocytes, increase in hyaline droplets and basophilic changes in the proximal tubular epithelium, erosion or focal necrosis in mucosa of stomach and atrophy of seminiferous tubular were found in male rats, and clear cell change of hepatocytes, atrophy of thymus, hypertrophy and hyperplasia of the interstitial cells in the ovaries were found in female rats. Anaemia, and an increase of leukocytes were also observed in male rats at 300mg/kg together with an increase in total cholesterol and decreases in GOT, albumin, A/G ratio, cholinesterase activity and triglycerides. In urinalysis, decreases in pH and specific gravity, an increase of urine volume were found at 300 mg/kg in male rats. At 60 mg/kg/day, reduced body weight gain was observed in females and enlargement and cortical vacuolation of the adrenals were found in both sexes. In addition, an increase of total cholesterol, a decrease of cholinesterase activity, and enlargement of the liver were found in male rats, and histopathological

changes in the liver, kidneys and the thymus were found in female rats. The NOELwas identified as12 mg/kg/day.

Reproduction/developmental toxicity
In an OECD Combined Repeated Dose and Reproductive/Developmental Screening Toxicity Test in rats, reduced fertility and implantation rates were observed at 300 mg/kg/day. These were probably caused by dysspermatogenesis. A birth index tended to low. There were no effects on the reproductive or developmental parameters of copulation, pregnancy, parturition or lactation. In an observation of neonates, no effects were found on the values for live pups, mean pup weights, sex ratio, abnormal pups or loss of offspring.

These results indicate that the no effect levels for reproduction or development are 60 mg/kg for sires, and 300 mg/kg for dams and offsprings.
NOEL for P generation: 60 mg/kg
NOEL for F1 generation: 300 mg/kg
NOEL for F2 generation: not applicable

Genetic toxicity
Bacterial test: Negative results in *S. Typhimurium* TA100, TA1535, TA98, TA1537 and *E. coli* WP2 uvrA with and without metabolic activation (Japanese TG).
Chromosomal Aberration in vitro: Marginal positive result in Chinese hamster liver (CHL) cells with metabolic activation (Japanese TG).
Micronucleus Test: Negative result (Japanese TG).

Name of substance	Diphenyl cresyl phosphate	
Abbreviation		
CAS No.	26444-49-5	
Endpoint	Value	Reference
LD50	6400mg/kg (rat, oral)	SIDS, 1998
NOAEL mg/kg bw	No information	
Reproductive toxicity	Reduced fertility at 300 mg/kg/day, NOEL 60 mg/kg/day	SIDS, 1998
Developmental toxicity	None (NOEL 300 mg/kg/day)	SIDS, 1998
Repeated dose Toxicity, NOEL rat	12 mg/kg/day	SIDS, 1998
Genotoxicity	Negative	SIDS, 1998
Carcinogenicity	No information	
Critical endpoint	Toxicity to liver, kidney and blood	Dose (NOEL) 12 mg/kg/day
Preliminary DNEL	DNEL for critical endpoint	Remarks
Workers, oral	8.4 mg/day	Default assessment factors Based on NOEL in repeated dose experiments
General population, oral	4.2 mg/day	
Workers, inhalation	0.84 mgm^{-3}	
General population, inhalation	0.21 mgm^{-3}	

Environmental effects

Triphenyl phosphate

Identity and properties

CAS number	115-86-6
Water solubility	1.9 mg/l at room temperature (Saeger *et al.*, 1979)
Vapour pressure	$2.4x10^{-3}$ Pa at 25°C (estimated from several values at elevated temperatures)
Log Kow	4.63 (Saeger *et al.*, 1979)

Fate data

Biodegradability	Readily biodegradable (CERI,2003)
Bioconcentration factor	420 (Muir *et al.*, 1983)

Aquatic effects

Species	Effect	Value	Reference
Fish (*Oncorhynchus mykiss*)	96 hr LC_{50}	0.31 mg/l	Sittichaikasen, 1978
Fish (*Oncorhynchus mykiss*)	30d EC_{10} (growth in sac fry)	0.037 mg/l	Sittichaikasen, 1978
Invertebrates (*Gammarus*)	96 hr EC_{50}	0.25 mg/l	Huckins *et al.*, 1991
Algae	26 hr IC_{50}	0.2-0.5	Wong and Chau, 1983
Algae	NOEC	0.1 mg/l	Wong and Chau, 1983

The PNEC for aquatic organisms based on the above data is 0.74 µg/l, derived by applying an assessment factor of 50 to the EC_{10} value for fish. Although the source data were compiled during preparation of a draft ESR risk assessment was prepared for triphenyl phosphate and can be considered reliable, there is uncertainty in the derived PNEC which is reflected in the use of an assessment factor.

Based on the above data, the substance does not meet the P, B or T criteria. Triphenyl phosphate is included on Annex 1 of Directive 67/548/EEC, with the classification R50/53.

Relative emissions: the emissions of HBCDD from industrial use in HIPS are related to the vapour pressure. Triphenyl phosphate has a significantly higher vapour pressure and so emissions from the same processes would be expected to be higher. Losses of HBCDD from articles during their service life are also related to the vapour pressure; hence emissions from service life would be expected to be higher. Triphenyl phosphate is readily biodegradable, so is expected to be degraded significantly in wwtps and to degrade in the environment.

Tetraphenyl resorcinol diphosphate

Identity and properties

CAS number	57583-54-7
Water solubility	0.69 mg/l at room temperature (Akzo Nobel, 2003)
Vapour pressure	2.7×10^{-6} Pa at 25°C (calculated using MPBPWIN v 1.28)
Log Kow	7.41 (calculated using KOWWIN v 1.60)

Fate data

Biodegradability	Inherently biodegradable (van Ginkel and Stroo, 1996)
Bioconcentration factor	No reliable measured data

Aquatic effects

Species	Effect	Value	Reference
Fish (*Danio rerio*)	96 hr LC_{50}	No effect at solubility	Geurts *et al.*, 2006
Invertebrate (*Daphnia magna*)	48 hr LC_{50}	0.76 mg/l	IUCLID, 2001
Invertebrate (*Daphnia magna*)	21 d NOEC (reproduction/mortality)	0.021 mg/l	Wetton and Mullee, 2001
Algae	72 hr	Slight effect at solubility	Kluskens et al, 2006

The PNEC for aquatic organisms based on the above data would be 0.42 µg/l, derived by applying an assessment factor of 50 to the *Daphnia* NOEC. Although the source data were compiled during preparation of a draft ESR risk assessment was prepared for tetraphenyl resorcinol diphosphate and can be considered reliable, there is uncertainty in the derived PNEC which is reflected in the use of an assessment factor.

Based on the above data, the substance does not meet the T criterion, but may meet the P or vP criteria and the B or vB criteria. Tetraphenyl resorcinol diphosphate is not included on Annex 1 of Directive 67/548/EEC.

Relative emissions: the emissions of HBCDD from industrial use in HIPS are related to the vapour pressure. Tetraphenyl resorcinol diphosphate has a similar vapour pressure and so emissions from the same processes would be expected to be similar. Losses of HBCDD from articles during their service life are also related to the vapour pressure and so emissions from service life would be expected to be similar. Tetraphenyl resorcinol diphosphate is inherently biodegradable, so is expected to be degraded to a greater extent than HBCDD in wwtps and in the environment.

Bisphenol A bis (diphenyl phosphate)

Identity and properties*

CAS number	5945-33-5 (sometimes given as 181028-79-5)
Water solubility	Practically insoluble (MSDS - Supresta, 2006)
Vapour pressure	24 Pa at 25°C (MSDS - Supresta, 2006)
Log Kow	-

The vapour pressure value seems very high for a substance of this structure and molecular weight . EPIWIN estimates a value of $3x10^{-6}$ Pa, which seems more realistic.

Fate data*

Biodegradability	Not readily biodegradable
Bioconcentration factor	Not expected to bioaccumulate in fish

Aquatic effects*

Species	Effect	Value	Reference
Fish (*Oncorhynchus mykiss*)	96 hr LC_{50}	>1 mg/l	MSDS (Supresta, 2006)
Invertebrates (*Daphnia magna*)	48 hr EC_{50}	>1 mg/l	MSDS (Supresta, 2006)
Invertebrates (*Daphnia magna*)	21 d NOEC	>1 mg/l	MSDS (Supresta, 2006)
Algae	72 hr EC_{50}	>1 mg/l	MSDS (Supresta, 2006)

* The property, fate and effects data given above are taken from an MSDS for this substance (Supresta, 2006).

No PNEC has been derived for bisphenol A bis (diphenyl phosphate). There is therefore uncertainty over whether it will have effects on aquatic organisms.

Bisphenol A bis (diphenyl phosphate) is listed in ELINCS (EC number 425-220-8). There is no information in ESIS for this substance and an IUCLID data set is not available. According to ELINCS, this substance is not classified in the Annex I of Directive 67/548/EEC as such, but it may be included in one of the group entries.

Trade names include: ADKSTAB FP-600
CR-741
FYROLFLEX BDP
NCENDX P-30

According to a European Flame Retardants Association fact sheet on bisarylphosphates (no date given) downloaded from the Internet, this substance is poorly biodegradable, but not toxic to fish, daphnia and algae. Bisphenol A bis (diphenyl phosphate) is not expected to bioaccumulate in fish.

Relative emissions: the emissions of HBCDD from industrial use in HIPS are related to the vapour pressure. Bisphenol A bis (diphenyl phosphate) has a predicted vapour pressure lower than HBCDD and so emissions from the same processes would be expected to be lower. Losses of HBCDD from articles during their service life are also related to the vapour pressure; hence emissions from service life would be expected to be lower. Bisphenol A bis (diphenyl phosphate) is not readily biodegradable, so is not expected to be degraded significantly in wwtps or to degrade in the environment.

Diphenyl cresyl phosphate

Identity and properties

CAS number	26444-49-5
Water solubility	2.6 mg/l at room temperature (Saeger et al., 1979)
Vapour pressure	6.3×10^{-5} Pa at 25°C (estimated from several values at elevated temperatures)
Log Kow	4.51 (Saeger et al., 1979)

Fate data

Biodegradability	Readily biodegradable (IUCLID, 2000)
Bioconcentration factor	200 (Bengtsson et al., 1983)

Aquatic effects

Species	Effect	Value	Reference
Fish (*Oryzias latipes*)	96 hr LC_{50}	1.3 mg/l	UNEP, 2002
Invertebrate (*Daphnia magna*)	24 hr LC_{50}	3.7 mg/l	UNEP, 2002
Invertebrate (*Daphnia magna*)	21 d NOEC (reproduction)	0.12 mg/l	UNEP, 2002
Algae	72 hr EC_{50}	0.99 mg/l	UNEP, 2002
Algae	72 hr NOEC	0.55 mg/l	UNEP, 2002

The PNEC for aquatic organisms based on the above data would be 2.4 µg/l, derived by applying an assessment factor of 50 to the *Daphnia* NOEC.

Based on the above data, the substance does not meet the P, B or T criteria. Cresyl diphenyl phosphate is not included on Annex 1 of Directive 67/548/EEC.

Relative emissions: the emissions of HBCDD from industrial use in HIPS are related to the vapour pressure. Cresyl diphenyl phosphate has a higher vapour pressure and so emissions from the same processes would be expected to be higher. Losses of HBCDD from articles during their service life are also related to the vapour pressure and so emissions from service life would be expected to be higher. Cresyl diphenyl phosphate is readily biodegradable, so is expected to be degraded significantly in wwtps and to degrade in the environment.

ALTERNATIVE FIRE RETARDANTS FOR USE IN TEXTILE BACKINGS

3.2.1.3 Textile alternatives

Health effects

Chlorinated paraffins/ATO

The acute oral toxicity of chlorinated paraffins of various chain lengths is low. Toxic effects such as muscular incoordination and piloerection were most evident following single exposure to short chain length chlorinated paraffins. On the basis of very limited data, the acute toxicity by the inhalation and dermal routes also appears to be low. Mild skin and eye irritation has been observed after application of short and intermediate (skin irritation) chain length chlorinated paraffins. Results of several studies indicate that short chain chlorinated paraffins do not induce skin sensitization.

In repeated dose toxicity studies by the oral route, the liver, kidney and thyroid are the primary target organs for the toxicity of the chlorinated paraffins. For the short chain compounds, increases in liver weight have been observed at lowest doses (lowest-observed-effect level is 50 to 100 mg/kg body weight per day and no-observed-effect level is 10 mg/kg body weight per day in rats). At higher doses, increases in the activity of hepatic enzymes, proliferation of smooth endoplasmic reticulum and peroxisomes, replicative DNA synthesis, hypertrophy, hyperplasia and necrosis of the liver have also been observed. Decreases in body weight gain (125 mg/kg body weight per day in mice), increases in kidney weight (100 mg/kg body weight per day in rats), replicative DNA synthesis in renal cells (313 mg/kg body weight per day) and nephrosis (625 mg/kg body weight per day in rats) have also been observed. Increases in thyroid weight, and hypertrophy and hyperplasia of the thyroid (LOEL of 100 mg/kg body weight per day in rats) and replicative DNA synthesis in thyroid follicular cells (LOEL of 313 mg/kg body weight per day) have been reported. At higher doses (1000 mg/kg body weight per day), thyroid function is affected, as determined by free and total levels of plasma thyroxine and increased plasma thyroid-stimulating hormone in rats.

For the medium chain compounds, effects observed at lowest doses are generally increases in liver and kidney weight (LOEL in rats of 100 mg/kg body weight per day; NOAEL in rats of 10 mg/kg body weight per day). Increases in serum cholesterol and "mild, adaptive" histological changes in the thyroid have been reported at similar doses in female rats (NOAEL of 4 mg/kg body weight per day).

For the long chain compounds, effects observed at lowest doses are multifocal granulomatous hepatitis and increased liver weights in female rats (LOAEL of 100 mg/kg body weight per day).

In the only identified reproduction study, no adverse reproductive effects were reported following exposure of rats to an intermediate chain length chlorinated paraffin with 52% chlorine. However, survival and body weights of the exposed pups were reduced (LOEL for non-significant decrease in body weight of 5.7-7.2 mg/kg body weight per day; LOAEL for decreased survival of 60-70 mg/kg body weight per day). In a limited number of studies of the developmental effects of the short, medium and long chain chlorinated paraffins, adverse effects in the offspring were observed for the short chain compounds only, at maternally toxic doses in rats (2000 mg/kg body weight per day). For the medium and long chain compounds, no effects on the offspring were observed even at very high doses (1000 to 5000 mg/kg body weight per day).

Chlorinated paraffins do not appear to induce mutations in bacteria. However, in mammalian cells, there is a suggestion of a weak clastogenic potential in vitro but not in vivo. Chlorinated paraffins are also reported to induce cell transformation in vitro.

Long term carcinogenicity studies by oral gavage in rats and mice have been conducted on a short chain chlorinated paraffin (C12; 58% Cl) and a long chain chlorinated paraffin (C23; 43% Cl). For the short chain compound in mice, there were increases in the incidence of hepatic tumours in males and females and tumours of the thyroid gland in females. In rats exposed to the short chain compound, there were increases in hepatic tumours in males and females, renal tumours (adenomas or adenocarcinomas) in males, tumours of the thyroid in females and mononuclear cell leukaemias in males. For the long chain chlorinated paraffin, the incidences of malignant lymphomas in male mice and tumours of the adrenal gland in female rats were increased.

In spite of the widespread use of chlorinated paraffins, there are no case reports of skin irritation or sensitization. This is supported by results of a limited number of studies in volunteers in which chlorinated paraffins have induced minimal irritancy in the skin, but not sensitization. (EHC).

Name of substance	Medium Chain Chlorinated Paraffins	
Abbreviation	MCCPs	
CAS No.	85535-84-9	
Endpoint	Value	Reference
NOAEL mg/kg bw	No data	
LD_{50}	No data	
Reproductive toxicity Adverse effects on pup body weight and condition in rats (LOEL) Foetal toxicity in rabbits NOEL	5 mg/kg/day 100 mg/kg/day	Serrone *et al.,* 1987 IRDC, 1983b; 1984
Repeated dose Toxicity, NOAEL Effects on liver and kidney in rats	10 mg/kg/day	Serrone *et al.,* 1987; Birtley *et al.* 1980
Genotoxicity	Negative	Serrone *et al.,* 1987; Birtley *et al.* 1980
Carcinogenicity	No information	
Critical endpoint	Effects on newborn in rats	Dose 5 mg/kg/day - LOEL
Preliminary DNEL	DNEL for critical endpoint	Remarks
Workers, oral	1.4 mg/day	Default assessment factors plus x5 for LOEL rather than NOEL
General population, oral	0.7 mg/day	
Workers, inhalation	0.14 mgm^{-3}	
General population, inhalation	0.35 mgm^{-3}	

Name of substance	Long Chain Chlorinated Paraffins	
Abbreviation	LCCPs	
CAS No.	85535-86-0	
Endpoint	Value	Reference
LD50	No information	
NOAEL mg/kg bw	No information	
Reproductive toxicity Foetal toxicity observed at dose causing maternal toxicity LOAEL in rabbits	100 mg/kg/day	IRDC, 1983c; 1981d; 1983d; 1982
Repeated dose Toxicity Granulomatous inflammation of the liver in female rats LOEAL NOAEL in mice	275 mg/kg/day 7500 mg/kg/day	NTP, 1986b; Bucher *et al.*, 1987
Genotoxicity	Negative	Birtley et al., 1980; NTP, 1986b; ICI, 1982b; Serrone et al., 1987
Carcinogenicity LOEL – benign lesions in the spleen - rats	Carcinogenic in animals 100 mg/kg/day	NTP, 1986b; Bucher *et al.*, 1987
Critical endpoint	Possible carcinogenicity and reproductive effects	Dose - 100 mg/kg/day - rats
Preliminary DNEL	DNEL for critical endpoint	Remarks
Workers, oral	28 mg/day	Default assessment factors plus x10 for LOEL rather than NOEL (to take account of severity of endpoint)
General population, oral	14 mg/day	
Workers, inhalation	2.8 mgm^{-3}	
General population, inhalation	0.7 mgm^{-3}	

Ammonium polyphosphates 68333-79-9

The Subcommittee on Flame-Retardant Chemicals, Committee on Toxicology, Board on Environmental Studies and Toxicology, National Research Council (2000) reviewed the toxicology of ammonium polyphosphates and their findings are summarised below.

No oral toxicity data for APPs were located for humans. Typical human dietary phosphorous levels are not harmful, especially in the presence of adequate calcium and vitamin D intake. The mean daily phosphorus dietary intake for adult males and females is estimated to be 1,500 mg/d and 1,000 mg/d, respectively. However, if the intake of phosphorus from processed foods was included in these values, the estimated dietary intake of phosphorous would be up to 20% higher.

It is known that high doses of ammonium ions can cause metabolic acidosis; persons with compromised liver function are at highest risk. Exposure to oral doses of 3.2 or 4.8 g ammonium/d as ammonium chloride for 5 d caused metabolic acidosis in two humans with compromised liver function (Sartorius et al. 1949). Effects secondary to acidosis include renal enlargement and demineralization of bone (ATSDR 1990).

The oral LD_{50} for a commercially available ammonium polyphosphate in rats was estimated to be >5,000 mg/kg (Inveresk 1990b). No deaths or clinical signs of toxicity were observed among five male and five female Sprague-Dawley rats given a single gavage dose of 5,000 mg/kg in distilled water and observed for 14 d. Weight-gain was normal in females during the second wk of the 2-wk observation period, but weight-gain in exposed males was reduced during the second wk. Gross post-mortem analysis of all dosed animals revealed no abnormalities.

No deaths or toxicity symptoms were observed among five male and five female Sprague-Dawley rats treated with a single gavage dose of 2,000 mg/kg in distilled water (Safepharm 1993f). Body weight gain was normal for all animals during both wk of the observation period and no gross abnormalities were detected at necropsy. Therefore, it was concluded that the LD_{50} for in rats is >2,000 mg/kg.

JECFA (1974) summarized a number of toxicity studies on phosphates and polyphosphate. The primary effect identified in these studies is kidney calcification (nephrocalcinosis), resulting from the precipitation of calcium phosphate due to an upset in phosphate homeostasis. JECFA (1974) noted that it is difficult to identify an effect level for nephrocalcinosis in toxicity studies because renal calcification occurs naturally to some extent in control rats which is determined by dietary intake of calcium and vitamin D.

Studies by van Esch et al. (1957, as cited in JECFA 1974) and Hodge (1964a, 1964b) suggest that chronic exposure of rats to 0.5% (sodium) polyphosphates in the diet may cause increased kidney weight but no kidney histopathology, while higher concentrations may cause kidney calcification when mineral levels are not equalized. Based on standard food intakes, 0.5% in the diet corresponds to a dose of about 200 mg/kg.

Reproductive and Developmental toxicity

No information was found regarding the reproductive or developmental effects of APPs following oral exposure. Information on reproductive and developmental effects of ammonium ions was also not located.

A study conducted by van Esch et al. (1957, as cited in JECFA 1974) found decreased fertility in rats that were treated with a mixture of one-third Kurrol's salt and two-thirds diphosphate at a dietary concentration of 5%. No reproductive effects were reported at lower concentrations.

Lang (1959, as cited in JECFA 1974), found no effects on reproduction in three generations of rats, each fed diets containing 0.4% or 0.75% phosphoric acid for 90 wk.

No effects on fertility, litter size, neonate growth, or neonate survival was observed in a three-generation reproduction study in groups of rats administered 0.5% sodium tripolyphosphate or 0.5% sodium hexametaphosphate (Hodge 1964a, 1964b, and BIBRA 1964). There was also no apparent effect on the histopathology of major organs of the third generation.

Genotoxicity

LR2 was not found to be mutagenic in 5 strains of *Salmonella typhimurium* (TA1535, TA1537, TA1538, TA98, TA100) exposed at concentrations of 25, 75, 250, 750, 2,500, or 5,000 µg LR2/plate in the presence or absence of exogenous metabolic activation (rat liver S9) (Safepharm 1995). No other genotoxicity data were located for APPs or for other polyphosphates.

Carcinogencity

No data are available on the carcinogenic effects of APPs by any route of exposure. Because of the absence of carcinogenicity data, the subcommittee concluded that the carcinogenic potential of APPs cannot be determined. Carcinogenicity data on ammonium ion or polyphosphates were not located. However, based on the physiological roles of these compounds they would not be expected to be carcinogenic.

Name of substance	Ammonium Polyphosphate	
Abbreviation		
CAS No.	68333-79-9	
Endpoint	Value	Reference
LD_{50}	>5000 mg/kg	Subcommittee on flame retarded chemicals
NOAEL mg/kg bw	2000 mg/kg	Subcommittee on flame retarded chemicals
Reproductive toxicity	No information	
Repeated dose Toxicity, NOAEL rat	200 mg/kg/day	Subcommittee on flame retarded chemicals
Genotoxicity	Limited data suggest not genotoxic	
Carcinogenicity	No information	
Critical endpoint	Possible kidney toxicity	
Preliminary DNEL	DNEL for critical endpoint	Remarks
Workers, oral	56 mg/kg	Default assessment factors plus additional uncertainty factor of x5 to allow for use of test data for sodium rather than aluminium polyphosphate Based on NOEL in repeated dose experiments with sodium polyphosphate
General population, oral	28 mg/kg	
Workers, inhalation	5.6 mgm^{-3}	
General population, inhalation	1.4 mgm^{-3}	

Environmental effects

Chlorinated Paraffins

Medium chain chlorinated paraffins (MCCPs)

Identity and properties

CAS number	85535-85-9 (C_{14-17})
Water solubility	0.027 mg/l for 51% wt. Cl (measured)* (EC, 2005)
Vapour pressure	2.7×10^{-4} Pa at 20°C for 45 and 52% wt. Cl* (EC, 2005)
Log Kow	5.52 - 8.21 for 45% wt. Cl 5.47 - 8.01 for 52% wt. Cl 7 (middle point of range of measured values)* (EC, 2005)

Fate data

Biodegradability	Not readily biodegradable (EC, 2005).
Bioconcentration factor	BCF 1,087 l/kg* (EC, 2005).

* Values used in the risk assessment as representative values for a commercial product (EC, 2005).

Aquatic effects

Species	Effect	Value	Reference
Fish (*Oncorhynchus mykiss*)	60 d NOEC	No adverse effects at 4.5 mg/l over 60 days for C_{14-17} 52% wt. Cl mixed with n-pentadecane-8-^{14}C 51% wt. Cl.	EC, 2005
Fish (*Oryzias latipes)*	20 day embryo-larval study	No adverse effects on embryos or larvae up to 1.6 and 3.4 mg/l over 20 days (two substances tested: $C_{14}H_{23.3}Cl_{6.7}$ 55% wt. Cl and $C_{14}H_{24.9}Cl_{5.1}$ 48% wt. Cl).	EC, 2005
Invertebrates (*Daphnia magna*)	21 d NOEC (reproduction)	10 µg/l for C_{14-17} 52% wt. Cl mixed with n-pentadecane-8-^{14}C 51% wt. Cl.	EC, 2005
Crustacean (*Gammarus pulex*)	96 hr LC_{50}	>1.0 mg/l for C_{14-17} 52% wt. Cl.	EC, 2005
Harpacticoid (*Nitocra spinipes*)	96 hr LC_{50}	9.0 mg/l for C_{14-17} 45% wt. Cl >10,000 mg/l for C_{14-17} 52% wt. Cl.	EC, 2005
Mussel (*Mytilus edulis*)	60 d NOEC	0.22 mg/l or C_{14-17} 52% wt. Cl mixed with n-pentadecane-8-^{14}C 51% wt. Cl.	EC, 2005
Algae (*Selenastrum capricornutum*)	96 hr NOEC (biomass) 72 hr NOEC (growth rate)	0.1 mg/l for C_{14-17} 52% wt. Cl mixed with n-pentadecane-8-^{14}C 51% wt. Cl (96 hr E_bC_{50} >3.2 mg/l) 0.049 mg/l for C_{14-17} 52% wt. Cl mixed with n-pentadecane-8-^{14}C 51% wt. Cl. (72 hr E_rC_{50} >3.2 mg/l).	EC, 2005

Long-term no observed effect concentrations (NOECs) have been reported for fish, *Daphnia*, mussels and algae. Effects have almost exclusively been observed on *Daphnia* (EC, 2005).

A PNEC of 1 µg/l has been derived for aquatic organisms by applying an assessment factor of 10 to the long-term NOEC of 10 µg/l obtained from the 21-day reproductive study with *Daphnia magna* on the basis that it is the most sensitive substance (EC, 2005).

Given that the ESR process involved a rigorous data searching and review process, with the possibility of the generation of new data through tests, the values reported in the RAR for MCCP can be considered to have little uncertainty.

MCCPs are currently classified with respect to their effects on human health and the environment as follows (as of September 2008):

- R64 (may cause harm to breastfed babies)
- R66 (repeated exposure may cause skin dryness or cracking)
- N; R50-53 (dangerous for the environment; very toxic to aquatic organisms – may cause long-term adverse effects in the aquatic environment)

No PBT assessment is included in the published version of the risk assessment (EC, 2005).

Relative emissions: the emission estimates for HBCDD from use in textiles are based largely on specific measurements. Therefore it is not appropriate to make an estimate of the relative emissions based on a comparison of the physico-chemical properties.

MCCPs are not readily biodegradable, so are not expected to be degraded significantly in wwtps or to degrade in the environment.

Long chain chlorinated paraffins (LCCPs)

Identity and properties

CAS number	85422-92-0 ($C_{\geq 18}$) and 63449-39-8 ($C_{18\text{-}32}$)
Water solubility	5 □g/l at 20°C for all LCCPS (EA, 2008)
Vapour pressure	2.5×10^{-4} Pa at 25°C for $C_{18\text{-}20}$ liquids (typically 40-52% wt. Cl) 2.5×10^{-5} Pa at 25°C for $C_{>20}$ liquids (typically 40-54% wt. Cl) 1.5×10^{-14} Pa at 25°C for $C_{>20}$ solids (typically 70% wt. Cl) (EA, 2008)*
Log Kow	9.7 for $C_{18\text{-}20}$ liquids (typically 40-52% wt. Cl) 10.3 for $C_{>20}$ liquids (typically 40-54% wt. Cl) 17 for $C_{>20}$ solids (typically 70% wt. Cl) (EA, 2008)*

* Vapour pressure and log kow values given above have been selected for use in the risk assessment for the three groups of long chain chlorinated paraffins considered (EA, 2008).

Fate data

Biodegradability	Unlikely to be readily or inherently biodegradable (EA, 2008)
Bioconcentration factor	BCF 1,096 l/kg for $C_{18\text{-}20}$ liquids BCF 192 l/kg for $C_{>20}$ liquids BCF < 1 l/kg for $C_{>20}$ solids (estimated values) (EA, 2008)

Aquatic effects

Species	Effect	Value	Reference
Fish (*Alburnus alburnus*)	14 d NOEC	≥125 µg/l for C_{18-26} 49% wt. Cl (no effects were seen at solubility).	EA, 2008
Fish (*Oncorhynchus mykiss*)	60 d NOEC	≥4 mg/l for C_{22-26} 43% wt. Cl ≥3.8 mg/l for $C_{>20}$ 70% wt. Cl (no effects were seen at solubility).	EA, 2008
Invertebrates (*Daphnia magna*)	21 d NOEC	29 µg/l for C_{18-20} liquid 52% wt. Cl	EA, 2008
Invertebrates (*Daphnia magna*)	21 d NOEC (reproduction)	≥55 µg/l for $C_{>20}$ liquid 43% wt. Cl (no effects were seen on reproduction).	EA, 2008

Based on the above data, the following PNECs have been derived for aquatic organisms using the long term NOECs from studies with *Daphnia magna*, and an assessment factor of 10:

C_{18-20} liquid $\quad PNEC_{water} = 2.9$ µg/l
$C_{>20}$ liquid $\quad PNEC_{water,\ screening} = 5.5$ µg/l
$C_{>20}$ solids $\quad PNEC_{water,\ screening} = 5.5$ µg/l

LCCPs are considered to potentially meet the persistent or very persistent criterion. They do not meet the toxic or bioaccumulative criterion. LCCPs are not listed in Annex 1 of Directive 67/548/EEC (EA, 2008). Given that the EA review involved a rigorous data searching and review process as undertaken for MCCPs, the values reported by the EA for LCCPs can be considered to have little uncertainty.

Relative emissions: the emission estimates for HBCDD from use in textiles are based largely on specific measurements. Therefore it is not appropriate to make an estimate of the relative emissions based on a comparison of the physico-chemical properties.

LCCPs are currently used in flame retardant textile coatings (EA, 2008).

Ammonium polyphosphates

Identity and properties

CAS number	68333-79-9
Water solubility	100% at 25°C (OECD, 2007)
Vapour pressure	Negligible* (OECD, 2007)
Log Kow	Not applicable to inorganic salts (OECD, 2007)

*Ammonium polyphosphate is an inorganic salt and will have negligible vapour pressure. Any measurable vapour pressure is due to the decomposition and release of ammonia gas.

Fate data

Biodegradability	Standard biodegradation tests are not applicable to inorganic salts. The ammonium present in APP may be nitrified (OECD, 2007).
Bioconcentration factor	APP is not expected to bioaccumulate as it has high aqueous solubility and will exist in a dissociated form in solution (OECD, 2007).

Aquatic effects

Species	Effect	Value	Reference
Fish (*Oncorhynchus mykiss*)	96 hr LC_{50}	>101 mg/l	OECD, 2007

Based on the above data, it is not possible to calculate a PNEC for the aquatic compartment. Given that these data come from an OECD SIAR, that has been reviewed internationally, it is assumed that there are no more data readily available. In the absence of a PNEC, there is uncertainty over what level should be used to assess exposures.

According to the ESIS website, this substance is not classified in the Annex I of Directive 67/548/EEC as such, but it may be included in one of the group entries.

Based on the above data, ammonium polyphosphate does not meet the P, B or T criteria, so is not a PBT substance.

Reactive phosphorous constituents

We have been unable to determine exactly what these substances are and there is no readily available information on their toxicity or environmental effects. It appears to have been assumed by KEMI (2006) and others that these compounds will have less impact on human health and/or the environment than brominated compounds, but there appear to be few data to support this assertion.

ALTERNATIVES TO EPS AND XPS INSULATION

3.2.1.4 Phenolic Foam

Health effects

The health issues associated with the use of phenolic foam are expected to be minimal. Toxic gas emission from phenolic foam is generally limited to carbon dioxide and carbon monoxide with very low levels of other gases. Phenolic foams can achieve very low toxic gas ratings in tests such as UK Naval Engineering Standard NES 713 and Scandinavian NordTest NT036. Phenolic foam has good fire resistance. There is a limited potential for dust inhalation during the installation of phenolic foam or during the removal of phenolic foam during building renovation or demolition.

Phenolic foams are made by a reaction of phenol and formaldehyde in the presence of a catalyst. There are potential health issues for workers involved in the manufacture of phenolic foam who may be exposed to these chemicals. Formaldehyde is irritating to mucous membranes at low levels of exposure and has been identified as a human carcinogen by IARC (2006). Phenol causes kidney and developmental toxicity in animals. IPCS (1994) identified NOAELS in rat studies in the range of 12-40 mg/kg body weight per day and recommended that the upper limit of total human daily intake should be in the range of 60-200 µg/kg body weight per day, equivalent to workplace exposure concentrations of 0.4-1.4 mgm^{-3} for an 8 hour shift. The UK Workplace exposure limits for formaldehyde and phenol are respectively as 8 hour time weighted averages. Formaldehyde is labelled as R23/24/25, 34, 40, 43 (Toxic by inhalation, in contact with the skin and if swallowed, limited evidence of a carcinogenic effect, may cause sensitisation by skin contact) and phenol is labelled as R23/24/25, 34, 48/20/21/22, 50/53 (Toxic by inhalation, in contact with the skin and if swallowed, danger of serious damage to health by prolonged exposure by inhalation, in contact with the skin or if swallowed, very toxic to aquatic organisms, may cause long-term serious effects in the aquatic environment).

Environmental effects

Formaldehyde

Identity and properties

CAS number	50-00-0
Water solubility	95% (w/w) at 120°C (theoretical solubility)* (UNEP, 2002)
Vapour pressure	5,185 hPa at 25°C (measured) (OECD, 2002)
Log Kow	0.35 (measured) (UNEP, 2002)

*At room temperature, pure aqueous solutions contain formaldehyde as methylene glycol and its oligomers. Aqueous solutions containing more than 30% (w/w) formaldehyde become cloudy at room temperature due to formation of larger poly(oxymethylene)glycols.

Fate data

Biodegradability	Readily biodegradable (UNEP, 2002)
Bioconcentration factor	Unlikely to occur (UNEP, 2002)

Aquatic effects

Species	**Effect**	**Value**	**Reference**
Fish (*Ictalorus melas*) (freshwater)	96 hr LC_{50}	24.8 mg/l	UNEP, 2002
Fish (*Morone saxatilis*) (marine)	96 hr LC_{50}	6.7 mg/l	UNEP, 2002
Invertebrates (*Daphnia pulex*)	48 hr EC_{50}	5.8 mg/l	UNEP, 2002
Invertebrates (*Daphnia pulex*)	48 hr EC_{50}	29 mg/l	UNEP, 2002
Algae (*Scenedesmus subspicatus*)	24 hr EC_{50} 24 hr EC_{10} (endpoint: oxygen production and consumption)	14.7 mg/l 3.6 mg/l	UNEP, 2002

The PNEC for aquatic organisms based on the above data would be 5.8 µg/l, derived by applying an assessment factor of 1,000 to the lowest valid effect value (48 hr EC_{50} of 5.8 mg/l) for *Daphnia pulex.*

Based on the above data, formaldehyde does not meet the P, B or T criteria, so is not a PBT substance.

Classification according to Annex 1 (ESIS website) for formaldehyde:
Carc. Cat 3; R40
T; R23/24/25
C; R34, R43

Formaldehyde is mainly used as an intermediate in the chemical industry for the production of condensed resins for the wood, paper and textile processing industries. Urea-formaldehyde foam insulation and formaldehyde disinfectants are important sources of formaldehyde exposure (OECD, 2002).

As this substance is used in a completely different way to HBCDD, an estimation of relative emissions is not appropriate.

Phenol

Identity and properties

CAS number	108-95-2
Water solubility	84 g/l at 20°C (EC, 2006)
Vapour pressure	0.2 hPa at 20°C (measured) (EC, 2006)
Log Kow	1.47 (measured) (EC, 2006)

Fate data

Biodegradability	Readily biodegradable (EC, 2006)
Bioconcentration factor	17.5 l/kg (EC, 2006)

Aquatic effects

Species	**Effect**	**Value**	**Reference**
Fish (*Oncorhynchus mykiss*)	96 hr LC_{50}	5.02 mg/l	EC, 2006
Fish (*Cirrhina mrigala*)	MATC (related to survival and growth of larvae) 60 d NOEC (derived from MATC)	77-94 µg/l 77 µg/l	EC, 2006
Invertebrate (*Cerodaphnia dubia*)	48 hr LC_{50}	3.1 mg/l	EC, 2006
Invertebrate (*Daphnia magna*)	16 d EC_{10} (growth reduction)	0.46 mg/l	EC, 2006
Algae (*Selenastrum capricornutum*	96 hr E_rC_{50} (growth inhibition)	61.1 mg/l	EC, 2006

The PNEC for aquatic organisms based on the above data would be 7.7 µg/l, derived by applying an assessment factor of 10 to the lowest NOEC (77 µg/l) for *Cirrhina mrigala.* [The NOEC is derived from a MATC of 77-94 µg/l with the assumption that the MATC is given as the range between the NOEC and the LOEC].

Annex I of Directive 67/548/EEC does not currently contain any environmentally relevant classifications for phenol. Classification according to Annex I (EC, 2006):
T; R 23/24/25
C; R 34
R 48/20/21/22
Muta. Cat. 3, R 68

Based on the above data, phenol does not meet the P, B or T criteria so is not a PBT substance.

Phenol is mainly used as an intermediate in organic synthesis for the production of bisphenol A, phenol resins, alkylphenols, caprolactam, salicylic acid, nitrophenols, diphenyl ethers, halogen phenols and other chemicals.

As this substance is used in a completely different way to HBCDD, an estimation of relative emissions is not appropriate.

3.2.1.5 Polyurethane and Polyisocyanurate Products

Health effects

These products do not give off volatile substances which in use and would not be expected to give rise to toxic exposures during use. There is a limited potential for dust inhalation during the installation or these products or during their during building renovation or demolition. These foams may be treated with brominated fire retardants to achieve required levels of fire resistance.

When subjected to burning, polyurethane foam systems will yield toxic fumes consisting of various gases, which may include, but not limited to, carbon monoxide, carbon dioxide and oxides of nitrogen, which may also present a risk to respiratory tract and eyes.

The manufacture of polyurethane and polyisocyanurate products involves the use of isocyanates which are potent respiratory sensitisers. There are potential health issues for workers involved in the manufacture of polyurethane foam who may be exposed to these chemicals. The UK workplace exposure limits for isocyanates calculated in terms of the mass of NCO groups present are 0.02 and 0.07 mgm^{-3} for an 8 hour shift or 15 short term exposure respectively.

Environmental effects

Tris(2-chloro-1-methylethyl) phosphate (TCPP)

This substance is used as a flame retardant additive for polyurethane. The main use of the treated polyurethane is in rigid foams for construction applications such as blocks and panels for insulation (EC, 2008c).

Identity and properties

CAS number	13674-84-5
Water solubility	1,080 mg/l at 20°C (measured) (EC, 2008b)
Vapour pressure	1.4×10^{-3} Pa at 25°C (measured) (EC, 2008b)
Log Kow	2.68 (measured) (EC, 2008b)

Fate data

Biodegradability	Inherently biodegradable, not fulfilling the criteria (EC, 2008b).
Bioconcentration factor	0.8-4.6 l/kg (2.7 l/kg, arithmetic mean) (EC, 2008b).

Aquatic effects

Species	Effect	Value	Reference
Fish (*Pimephales promelas*)	96 hr LC_{50}	51 mg/l	EC, 2008b
Invertebrate (*Daphnia magna*)	48 hr EC_{50}	131 mg/l	EC, 2008b
Invertebrate (*Daphnia magna*)	21 d NOEC (reproduction)	32 mg/l	EC, 2008b
Algae (*Pseudokirchneriella subcapitata*)	72 hr E_rC_{50} (growth rate) 72 hr EbC_{50} (biomass)	82 mg/l 33 mg/l	EC, 2008b
Algae (*Pseudokirchneriella subcapitata*)	72 hr E_rC_{10} (growth rate) 72 hr E_bC_{10} (biomass) 72 hr NOEC	42 mg/l 14 mg/l 13 mg/l	EC, 2008b

The PNEC for aquatic organisms based on the above data would be 0.64 mg/l, derived by applying an assessment factor of 50 to the long-term NOEC for *Daphnia magna.* Given that the ESR process involved a rigorous data searching and review process, with the possibility of the generation of new data through tests, the values reported in the RAR for this substance can be considered to have little uncertainty.

Tris(2-chloro-1-methylethyl) phosphate is not currently included on Annex I of Directive 67/548/EEC. Based on the above data, tris(2-chloro-1-methylethyl) phosphate is not a PBT substance.

This substance is used in a different material to HBCDD, and the processes involved may be different, hence it is not possible to make an estimate of the relative level of emissions through comparison of the substance properties with HBCDD.

3.2.1.6 Mineral wools and other mineral products

Health effects

These systems employ inert materials such as fibre glass, glass wool, rock wool and gypsum that do not represent a hazard to building occupants when used as insulation. Although formaldehyde and phenolic resins may be used to bind these products, emissions to indoor air are extremely low and do not impact on indoor air quality. These materials are innately fire and heat resistant. There is potential for dust inhalation during the installation of these products or during building renovation or demolition. In the UK, the workplace exposure limit for all machine-made mineral fibres is 5 mgm^{-3} as inhalable dust or 2 fibres/ml, which ever is reached first. These materials are not classified as carcinogenic. Gypsum is a low toxicity dust and the UK workplace exposure limits would be 4 and 10 mgm^{-3} for the respirable and inhalable fractions respectively.

Environmental effects

The industry (EUROSIL: http://www.eurisol.com/pages/waste_sustainability.htm claim that for each tonne of CO2 generated in the manufacturing process of mineral wool, about 200 tonnes of CO2 are saved by its thermal insulation properties over a 50-year period and that producing mineral wool requires only half the energy needed to manufacture other types of insulation. EUROSIL also claim that there has been a steady decrease in energy inputs and emissions during production over time. In addition, the industry claim to be using increasing amounts of recycled materials in manufacture. Depending on the quality and availability of local supplies recycled glass now makes up 30% to 60% of the raw material input. In some plants this is as high as 80%.

Following end of life removal from buildings, there is an increasing trend to recycle these materials, otherwise they may be disposed of as inert construction waste and are unlikely to have a major adverse impact on the environment.

3.2.1.7 Cellulose fibre

Insulation products based on cellulose recovered from the recycling of paper and similar materials have been promoted as a green alternative to traditional insulation systems. Cellulose fibres are believed to represent a relatively low health hazard for humans and the UK workplace exposure limits for respirable and inhalable dust are 4 and 10 mgm^{-3} respectively as an 8 hour time weighted average. There is also a 15 minute exposure limit for inhalable dust of 10 mgm^{-3}.

In order to meet fire safety standards and also in order to prevent rodent or other pest damage, cellulose fibre insulation must be treated with fire retardant and persistent pesticides to be effective in use. Potentially, the presence of these added chemicals would lead to human health hazards and potential environmental effects that were at least as serious as those associated with EPS or XPS. Some (perhaps all) cellulose insulation products marketed in the EU contain inorganic boron salts that have been added in sufficient quantity to meet fire safety regulations and to provide adequate pest protection. The IPCS (1998) report that animal experiments have shown that boron in the form of inorganic salts (borates) gives rise to reproductive and developmental toxicity in animals and calculated that the tolerable intake (TI) of boron for humans as 0.4 mg/kg body weight per day, equivalent to 28 mg/day for a 70 kg adult. The American Conference of Industrial Hygienists (ACGIH) recommend Threshold Limit Values for inorganic borates of 2 mgm^{-3} and 6 mgm^{-3} as an 8 hour time weighted average and 15 minute maximum exposure concentrations respectively. The 8 hour limit would give a daily intake equivalent to 20 mg. The US EPA oral reference dose (ie dose at which repeated exposure would be expected to cause no significant hazard to health) for boron is 0.2 mg/kg/day (equivalent to an adult intake of 14 mg/day) to protect against reproductive and developmental effects (http://www.epa.gov/NCEA/iris/subst/0410.htm). The US ATSDR indicate that the short and intermediate term Minimal Risk Levels for oral intake are 0.2 mg/kg/day and also give a draft inhalation minimal risk level for acute respiratory effects of 0.01 mgm^{-3} (for community rather than workplace exposure; http://www.atsdr.cdc.gov/mrls/index.html).

The IPCS (1998) indicate that boron has a low aquatic toxicity.

3.2.1.8 Intumescent systems

We have been unable to find relevant health or environmental information.

ALTERNATIVES TO HIPS

3.2.1.9 Polyethylene with Magnesium Hydroxide

Health effects

The available data is not sufficient to conduct a health screening of magnesium hydroxide, but indicate that the substance can be regarded as relatively harmless in small quantities as the substance is used as food additive.

Repeated or prolonged human exposure to larger quantities of the substance may imply adverse impact on human health, such as general irritation and malaise. There may be lung effects at high particulate concentrations and central nervous system depression at very high doses.

The ISCS on polyethylene indicates low toxicity.

Environmental effects

Polyethylene is a persistent waste material, although an increasing quantity is being recycled. Ingestion of polyethylene particles by animals is a growing problem, particularly in marine ecosystems. Organisms may ingest plastics in preference to food. The release of small quantities of magnesium hydroxide to the environment would not be expected to cause toxicity. The disposal of large quantities in a restricted area of water or disposal onto soil could have a substantial impact on alkalinity levels with consequent impacts on flora and fauna.

3.2.2 Technical and economical feasibility and availability

ALTERNATIVE FIRE RETARDANTS FOR USE IN HIPS, EPS AND XPS

3.2.2.1 Halogenated flame retardants in conjunction with Antimony Trioxide

Technical feasibility

Diantimony trioxide is an effective flame retardant synergist used in conjunction with a source of halogen such as halogenated flame-retardants or PVC. It is used in plastics, rubber and textiles (EC, 2008). Diantimony trioxide has a wide range of applications and is used in polymers such as polypropylene, polyethylene, EDPM, ABS, HIPS (electrical components, appliance housings etc), flexible polyurethane, TPU, unsaturated polyesters, epoxies, phenolics and engineering thermoplastics such as PBT (Great Lakes, http://www.e1.greatlakes.com/corp/common/jsp/index.jsp).

Decabromodiphenylethane is a general purpose additive flame retardant for a variety of polymer applications and textiles. It is used in ABS, HIPS, polypropylene and polyethylene, polycarbonate, polybutylene terephthalate and polyethylene terephthalate, PVC, thermoplastic elastomers, epoxy resins and unsaturated polyesters. Applications include building insulation and roofing materials, wire and cable insulation, coatings, and electrical and electronic applications (particularly those made from HIPS such as TV housings) (EA, 2007). Ehylene bis(tetrabromophthalimide) is used as a flame retardant in a range of applications including HIPS, ABS, thermoplastic polyester, polycarbonate, polypropylene and polyethylene, polyolefin, PVC and elastomers (Albemarle, http://www.albemarle.com/).

HBCDD provides effective flame retardant properties at low loadings in HIPS, EPS and XPS that do not adversely impact the mechanical properties of these materials. Other fire retardants are only effective at much higher loadings which adversely affect the mechanical properties of HIPS, EPS and XPS. The higher loadings would also lead to greatly increased manufacturing costs (KEMI, 2006).

The EPS sector group of Plastics Europe which represents 90% of the EPS producers in Europe has been involved in a five year investigation to identify alternatives to HBCDD in EPS. They concluded that there are currently no candidate molecules, either commercially available or “novel” compounds which are seen as feasible alternatives to HBCDD in EPS. A similar research project undertaken for XPS foams has drawn the same conclusions (Briefing note provided to IOM by the HBCD Industry User Group, October, 2008).

In a review of the use of various hazardous substances in consumer products the Norwegian Pollution Control Authority concluded that although no other flame retardant that can fully replace HBCDD in all areas, but there are other different brominated and non-brominated flame retardants that can be used in electrical/electronic products (SFT, 2007).

Economic feasibility

The Danish EPA (2007) provide indicative prices for HIPS containing deca-BDE and alternative flame retardants (i.e. compounded), as shown in the table below.

Polymer/compound	**European price range (€/kg)**
Standard HIPS	0.95-1.25
HIPS + deca-BDE	1.50-1.80
HIPS + other BFR	
- UL 94 V-0	1.90-2.10
- UL 94 V-1	1.70-1.90
HIPS/PPE + halogen-free FR	2.30-2.90

In addition, RPA (2002) cite information from IVL (1997) on prices of various types of flame retardants, as shown below.

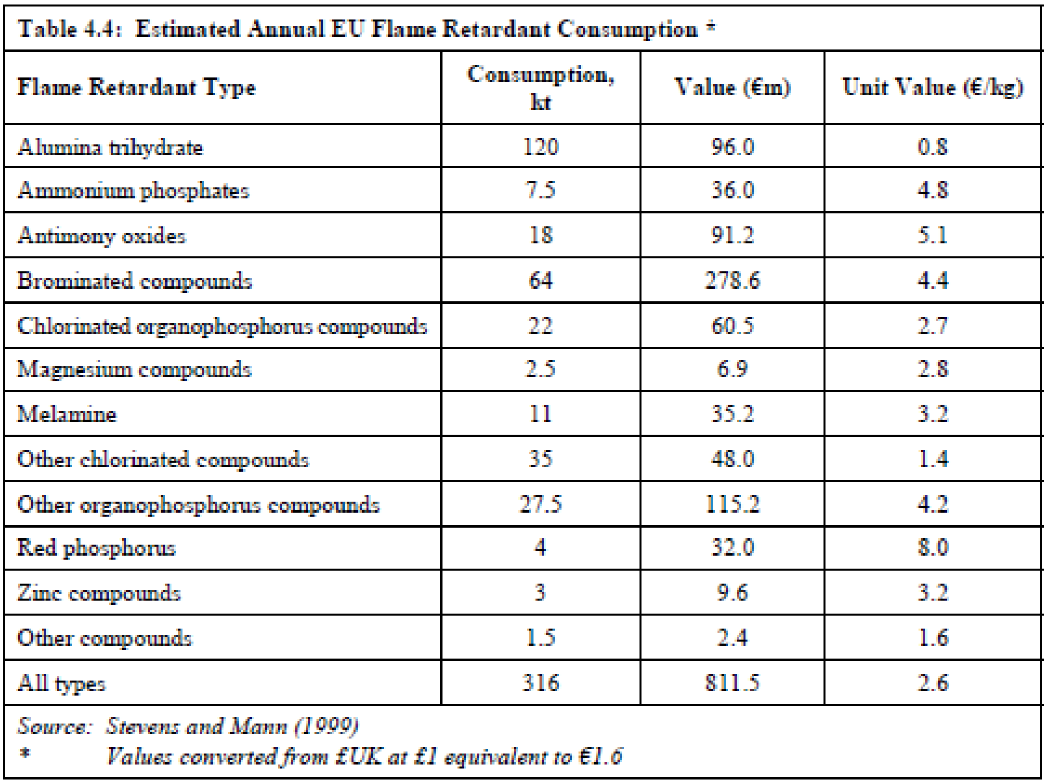

Table 4.4: Estimated Annual EU Flame Retardant Consumption *

Flame Retardant Type	**Consumption, kt**	**Value (€m)**	**Unit Value (€/kg)**
Alumina trihydrate	120	96.0	0.8
Ammonium phosphates	7.5	36.0	4.8
Antimony oxides	18	91.2	5.1
Brominated compounds	64	278.6	4.4
Chlorinated organophosphorus compounds	22	60.5	2.7
Magnesium compounds	2.5	6.9	2.8
Melamine	11	35.2	3.2
Other chlorinated compounds	35	48.0	1.4
Other organophosphorus compounds	27.5	115.2	4.2
Red phosphorus	4	32.0	8.0
Zinc compounds	3	9.6	3.2
Other compounds	1.5	2.4	1.6
All types	316	811.5	2.6

Source: Stevens and Mann (1999)
* *Values converted from £UK at £1 equivalent to €1.6*

Based on these sources of information, the following broad conclusions can be drawn:

Raw material costs for deca-BDE appear to be less than for other brominated flame retardants. Therefore, it is likely that the purchase price of this potential alternative would be less than that for HBCDD.

There is insufficient available information to make distinctions between HBCDD and other brominated flame retardant costs. They may be expected to be broadly similar.

Chlorinated alternatives and particularly chlorinated paraffins are expected to be less expensive than HBCDD.

For use of any alternative flame retardant, there would be additional one-off costs of substitution associated with, for example, product testing and changes to processing equipment which cannot readily be quantified.

3.2.2.2 Organic Aryl Phosphorous Compounds

These compounds are not generally regarded as technically or economically viable alternatives to HBCDD in HIPS, EPS or XPS for the reasons described above for antimony trioxide based systems. They may be technically viable alternatives to HBCDD for some specific product types.

Technical feasibility

HBCDD is used in four principal product types; EPS (insulation), XPS (insulation), HIPS (electrical and electronic parts) and polymer dispersion for textiles. Producers' websites have been checked to see if they recommend HBCDD is used in four principal product types; EPS (insulation), XPS (insulation), HIPS (electrical and electronic parts) and polymer dispersion for textiles. Producers' websites have been checked to see if they recommend triphenyl phosphate, tetraphenyl resorcinol disphosphate, cresyl diphenyl phosphate or bisphenol A bis (diphenyl phosphate) for use in the same areas as HBCDD. According to the producers' websites, triphenyl phosphate is recommended for use in HIPS, consumer electronics, appliance housings and TV housings. Tetraphenyl resorcinol disphosphate is recommended for use in consumer electronics, appliance housings, TV housings, construction, insulation and mattresses. It is also used in engineered resins such as modified PPO, polycarbonate/styrenic blends, polyesters and HIPS. HBCDD is used in four principal product types; EPS (insulation), XPS (insulation), HIPS (electrical and electronic parts) and polymer dispersion for textiles. Cresyl diphenyl phosphate is recommended for use in construction, insulation, furniture, mattresses, textiles, and wall and floor coverings. Bisphenol A bis (diphenyl phosphate) is recommended for use in the electrical and electronics industry, enclosures made out of ABS/PC blends, thermosplastics including ABS and HIPS, and engineered resin applications such as polyphenylene oxide alloys and PC/ABS.

Economic feasibility

Based on information from RPA (2002), organophosphorus compounds could be expected to be broadly similar in price to that of HBCDD per unit mass of flame retardant.

However, the Bromine Science and Environment Forum (quoted in Kemi, 2006) indicate that greater quantities of non halogen flame retardants are required to achieve the same overall level of fire protection. This would tend to suggest that the overall raw material cost would be higher than for HBCDD. This is supported by data from the Danish EPA (2007) (above) which suggests significantly higher compound costs for HIPS/PPE with halogen-free flame retardant (€2.3-€2.9 per kg compound compared to €1.7-€2.1 kg for a brominated flame retardant). Whilst the price per unit of compound is relatively moderate, this implies a potentially significant increase in cost of flame retardant[3]. The Danish EPA (2007) estimated that the cost of producing HIPS with a halogen-free flame-retardant rather than a brominated flame-retardant (other than Deca-BDE) would increase the raw material price with about 4-5 EUR for a full enclosure of an average TV-set.

Again, there would be additional one-off costs of substitution associated with, for example, product testing and changes to processing equipment which cannot readily be quantified.

ALTERNATIVE FIRE RETARDANTS FOR USE IN TEXTILE BACKINGS

3.2.2.3 Textile Alternatives

Technical feasibility

KEMI (2006) indicate that reactive phosphorus constituents, ammonium polyphosphate, diammonium phosphate and intumescent systems are commercially available alternatives to HBCDD but do not provide information about performance or cost.

Ammonium polyphosphate is primarily used as a fertiliser (OECD, 2007). An Internet search revealed that this substance is used as a flame retardant in textiles for fabric back coating and in the production of flame retardant furnishing and mattress ticking. Ammonium polyphosphate is also used as the catalyst component in intumescent formulation. Aqueous solutions of ammonium polyphosphate can be used in the flame retardant treatment of cellulosic materials (http://www.albemarle.com/).

The use of fire retardant systems involving antimony trioxide is restricted by the white pigmenting behaviour of ATO which means that it is unsuitable for applications where a transparent backing is required.

Although median-chain chlorinated parafins have been identified as a potential alternative to HBCDD for textile coating, the EC (2005) reported that there was no use of medium-chain chlorinated paraffins in textiles in the EU at that time; however the report did identify that some of the medium-chain chlorinated paraffins supplied to the PVC industry was used for coating applications, including textiles. Long-chain chlorinated paraffins are used for backcoating textiles. A limitation on the use of MCCPs in this area may be that the maximum chlorine content achievable is lower than for SCCPs and LCCPs.

In their review of the use of various hazardous substances in consumer products the Norwegian Pollution Control Authority concluded that there are other different brominated and non-brominated flame retardants that can be used in place of HBCDD for textile coatings (SFT, 2007).

Economic feasibility

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[3] For example, even taking a conservative assumption that 1kg of compound contains 7% HBCDD and assuming a price increase per kg of compound from €2.1 to €2.3 per kg, this would imply a price increase of around €3 per kg of flame retardant, assuming use in equivalent quantities.

As indicated above, the costs of deca-BDE are expected to be comparable or slightly lower than that for HBCDD and the cost of chlorinated paraffins is expected to be lower than that for HBCDD.

Again, there would be additional one-off costs of substitution associated with, for example, product testing and changes to processing equipment which cannot readily be quantified.

ALTERNATIVES TO EPS AND XPS INSULATION

3.2.2.4 Overview

A wide range of insulation products are available. KEMI (2007) reported that there are different views have been given on the economic impact of introducing a restriction on the use of HBCDD in EPS and XPS. Producers of EPS/XPS, building industry and authorities in 33(40) countries with little use, e g Sweden and Denmark indicate little or no consequences, whereas in countries with a large use, e g Poland and Germany, respondents indicate potentially severe consequences, in particular on small and medium sized enterprises (SMEs).

3.2.2.5 Phenolic Foam

Phenolic foam insulation is commercially available in the EU but does not appear to have a significant share of the insulation market. The European EPS trade association (EUMEPS) claim to have a 35% share of the total construction insulation market in Europe (http://www.propubs.com/GI/Articles/eGI_Sep07_EPS.pdf) and it seems likely that the XPS market share will be of similar size. In addition, the Global Insulation trade association only consider EPS, XPS and mineral wool in their recent(2008) review of market trends, which suggests that the market share for phenolic foam is low (http://www.propubs.com/GI/Articles/eGI_May08_ExaneBNPParibas.pdf). The European Phenolic Foam Association (EPFA; http://www.epfa.org.uk/Pdfs/eng.pdf) claim that phenolic foam has exceptional fire performance with very low flame spread, negligible smoke emission and a very low level of toxic gas emissions and that it meets the fire certification requires of UK Class 0, Dutch NEN 6065/6055 Class 1, German B1, Belgian A1, French M1 and Scandinavian NT 036 Class 1. It has an excellent strength/density ratio and offers a range of thermal conductivity performance and is up to 50% more thermally efficient than competing products. In terms of environmental performance, EBPF claim low embedded energy costs compared with other insulation materials, a potentially significant contribution to reducing carbon emissions and availability free of CFCs and HCFCs.

The relatively small market share held by phenolic foam insulation may indicate that it is a relatively expensive product to use. Although no information about relative costs was identified in our searches, there is, a substantial market for these products in the US suggesting that it may be a economically feasible alternative for some applications. The US consumption of phenolic resins for insulation products in 2001 was 106 thousand metric tonnes. This consumption was anticipated to increase to 115 thousand metric tonnes in 2006.

Polyurethane and Polyisocyanurate Products

Insulation products based on polyurethane and polyisocyanurate foams are commercially available but are less widely manufactured in the EU than EPS/XPS or mineral wool products (www.propubs.com/GI/Articles/eGI_May08_ExaneBNPParibas.pdf). They are used for a range of building insulation applications including cavity wall insulation, roof insulation (but not loft insulation) and in timber frame/stud walls.

UBA (2000) provide a comparison of relative costs of material per area unit insulated to a specific insulation performance. If EPS = 1, mineral wool = 1.3, polyurethane = 2.8 and XPS = 3 (raw material costs only). Therefore, the raw material cost of polyurethane may be expected to be slightly less than that for XPS but more than that for EPS. This includes only the materials costs and dose not take account of any required changes in construction techniques or supporting construction materials.

3.2.2.6 Mineral wools and other mineral products

Fibre glass, rockwool and other mineral wools have a large share of the insulation market in Europe (>30%) and there would appear to be economically and technically viable alternatives to EPS and XPS for many applications. Differences in mass density and in resistance to water damage might influence technical feasibility in some applications. Based on the above comparison in UBA (2000), the raw material cost of mineral wools may be expected to be slightly more than that for EPS but less than that for XPS.

3.2.2.7 Cellulose fibre

Insulation products based on cellulose fibre are commercially available but not widely used. It is available in the UK for use in loft insulation, application to sloping ceilings/between rafters and in timber frame/stud walls/dry lining and suspended floors but not for cavity wall insulation, It is most effective where “breathable” insulation is required as it has the capacity to absorb and release moisture. It does however have a poor moisture resistance and will degrade in damp conditions. Given the high prevalence of building dampness, poor moisture is likely to limit the range of building insulation applications for cellulose fibre in much of European except in the most southerly member states. We have been unable to find information about the cost of cellulose fibre insulation relative to XPS/EPS.

3.2.2.8 Intumescent systems

We have been unable to find relevant information on technical and economic feasibility.

ALTERNATIVES TO HIPS

3.2.2.9 Polyethylene with Magnesium Hydroxide

KEMI (2006) indicate that polyethylene with magnesium hydroxide is a commercially available alternative to HIPS for the housing of electronic products and wiring parts but do not provide any information about its performance or cost relative to that of HIPS.

In general, based for example on information from RPA (2002), it could be expected that use of polyethylene containing magnesium hydroxide would be less expensive in terms of raw material costs than HIPS containing HBCDD. However, there would be additional one-off costs of substitution associated with, for example, product testing and changes to processing equipment which cannot readily be quantified.

3.3 Summary table

For the major uses of HBCDD, namely in EPS/XPS there does not appear to be a fire retardant available that will provide equivalent performance. The main benefit of HBCDD is that it offers unique performance in polystyrene foams because it is effective at low levels (around 0.7% in EPS, 2.5% in XPS) (EC RAR, 2008). Higher quantities of non-halogen flame-retardants are required in order to get the same level of fire protection. This means that the qualities of the polymer (e.g. thermal insulation) are not as impaired using HBCDD as they would be with a flame retardant used in higher quantities. Higher production of non-halogen alternatives would lead to increase in manufacturing and transportation costs. In addition, the structural performance of EPS and XPS is impaired at higher fire retardant loadings.

There are commercially available alternatives to EPS/XPS for use in building insulation that represent technically feasible substitutes in many, but not necessarily all applications. Mineral wools are already in wide use and have a share of at least 30% in the European building insulation market indicating that they represent technically and economically viable alternatives to EPS/XPS in many applications. There may, however, be applications where the lower mass density or better moisture resistance of EPS/XPS are important. Phenolic foam is another commercially available product that meets relevant fire safety standards and has a low density, is moisture resistant and highly thermally efficient. It is primarily used in applications where moisture resistance or thickness are important and has only a small share of the European market for insulation. This may indicate that it is relatively expensive. These alternative insulation materials are not particularly hazardous for human health or environment, although the chemicals used in the manufacture of phenolic foam are hazardous to human health. There may also be significant differences between the various insulation products in terms of the net carbon savings that arise over the life cycle from manufacturing to disposal.

There are commercially available alternative fire-retardants available to the use of HBCDD in HIPS and textile coatings, including non-halogenated flame retardants that provide the same level of fire protection and performance. The relatively small quantity of HBCDD used in these applications may reflect the availability of competing products that do not contain HBCDD, but are equally effective in use.

Table 3.2 summarises the health, environment and feasibility information available for alternatives to HBCDD.

Table 3.2: Summary of alternatives to HBCDD

Use	Alternative	Toxicity	Ecotoxicity	Cost	Availability	Use pattern	Performance
Fire retardants in HIPS	Antimony trioxide (ATO)	Potential human carcinogen and reproductive toxicant	Not readily biodegradable , low to moderate bioaccumulation potential	Not directly comparable (synergist)	Commercially available	Used as a synergist with other flame retardants	Technically viable alternative
	Decabromodiphenylether/ATO	Neurotoxicant	Not readily biodegradable , low to moderate bioaccumulation potential	Comparable or slightly lower raw material price. Additional one-off costs.	Commercially available	Used in HIPS at approx 10-15% by weight, and three parts to 1 part ATO	Technically viable alternative
	Decabromodiphenylethane/ATO	Limited data, but likely to be of low toxicity	Not readily biodegradable, may be persistent	Comparable raw material price. Additional one-off costs.	Commercially available	Used in HIPS at approx 10-15% by weight, and three parts to 1 part ATO	Technically viable alternative
	Ethylenebis(tetrabromo phthalimide)/ATO	Low toxicity	Not biodegradable and is persistent. Non-toxic.	Comparable raw material price. Additional one-off costs.	Commercially available	Used in HIPS at approx 10-15% by weight, and three parts to 1 part ATO	Technically viable alternative
	Triphenyl phosphate	Chronic toxicant with effects on liver	Readily biodegradable, toxic to aquatic organisms	Likely higher raw material cost Additional one-off costs.	Commercially available	11-13% by weight	Technically viable alternative

Use	Alternative	Toxicity	Ecotoxicity	Cost	Availability	Use pattern	Performance
	Resorcinol bis (biphenyl phosphate)	Chronic toxicant with effects on liver	Inherently biodegradable, may be persistent and bioaccumulative	Likely higher raw material cost Additional one-off costs.	Not currently in widespread use as a flame retardant		Technically viable alternative
	Bis phenol A bis (biphenyl phosphate)	Limited data, likely to be of low toxicity	Poorly biodegradable. Non-toxic and is not bioaccumulative	Likely higher raw material cost Additional one-off costs.	Commercially available		
	Diphenyl cresyl phosphate	Chronic toxicant with effects on liver, kidney and blood. Effects on fertility	Readily biodegradable	Likely higher raw material cost Additional one-off costs.	Commercially available		Technically viable alternative
Alternatives to HIPS	Polyethylene with Magnesium Hydroxide	Insufficient data but likely to be of low toxicity	Polystyrene particles are an issue in aquatic environments	Likely lower raw material cost. Additional one-off costs.	Commercially available		Technically viable alternative
Textiles	decabromodiphenylether	Neurotoxicant	Not readily biodegradable , low to moderate bioaccumulation potential	Comparable or slightly lower raw material price. Additional one-off costs.	Commercially available	25% by weight (in conjunction with ATO	Technically viable alternative where transparency is not required

Use	Alternative	Toxicity	Ecotoxicity	Cost	Availability	Use pattern	Performance
	chlorinated paraffins	Reproductive toxicant, chronic toxicity with effects of liver and kidneys, potential carcinogen	LCCPs are considered to potentially meet the persistent or very persistent criterion. They do not meet the toxic or bioaccumulative criterion.	Likely lower raw material cost. Additional one-off costs.	Commercially available		Technically viable alternative
	ammonium polyphosphates	Low toxicity	Not an ecotoxicant	Likely higher raw material cost Additional one-off costs.	ammonium polyphosphates		Technically viable alternative
EPS/XPS	Phenolic Foam	Low toxicity in use but manufactured from materials toxic and carcinogenic		Expensive?	Commercially available, but only a small share of insulation market		Extremely high thermal efficiency

Use	Alternative	Toxicity	Ecotoxicity	Cost	Availability	Use pattern	Performance
	Polyurethane and polyisocyanurate products	May emit toxic fumes if burnt, otherwise low toxicity in use, but manufacture involves the use of isocyanates – potent respiratory sensitisers		Material cost likely less than XPS; more than EPS	Commercially available, but less widely manufactured in EU than EPS/XPS	These products use the following flame retardant chemicals: tris monochloropropyl phosphate (TMCPP), tris chloroethyl phosphate (TCEP), and RB-79 (diol made from tetrabromo phthalic anhydride)	Widely used as building insulation –as effective as EPS/XPS in many applications
	Mineral wools	Dust inhalation hazard during installation and removal; negligible emissions during use	Minimal	Material cost likely less than XPS; more than EPS	Commercially available with substantial share of insulation market		Widely used as building insulation –as effective as EPS/XPS in many applications; transport costs, building load considerations and moisture resistance may favour XPS/EPS under some circumstances

Use	Alternative	Toxicity	Ecotoxicity	Cost	Availability	Use pattern	Performance
	Cellulose fibre	Exposure to low toxicity dust during installation and removal ; potential exposure to flame retardants and pesticides; inorganic boron salts are widely used and are potential reproductive and developmental toxins	Potential release of flame retardants and pesticides; boron is a widely used additive to cellulose fibre insulation and is believed to have a low aquatic toxicity and is naturally present in the environment	More expensive than traditional insulation methods	Commercially available but not widely used		Moisture sensitivity is a possible issue in many building insulation applications
	Intumescent systems	Inadequate data	Inadequate data	Inadequate data	Inadequate data	Inadequate data	Inadequate data

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Annex 1: List(s) of information requirements for priority setting and specification of conditions for authorisation

The formats provided in this Annex serve as examples of possible templates that may be used by the contractor to report the requested data and information. Other formats (containing the requested data and information) are acceptable after consultation with ECHA.

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Table 1: Overview on tasks related to work package 1 (grey shaded fields not relevant)

Manufacture, trade and formation	**Process** (narrative description)	**Locations** (number of M sites; spatial distribution) [2]	**Tonnage manufactured, imported, exported or formed**	**Releases to working environment** [3]	**Releases to environment** (t/y released to air, wastewater or to waste)
Manufacture EU Process A	Batch-process: Elementary bromine added to cyclododecatriene in solvent.	1; Netherlands	t/y 6000	Production workers: Inhalable HBCDD: 1.2 mgm^{-3} Dermal exposure powder: 170 mg/day Dermal exposure granules 17 mg/day Process runs intermittently, exposure occurs <25% of time.	t/y 0.002 (a) $1x10^{-4}$ (ww)
Manufacture EU Process B	Micronising	small number, Belgium, unknown	1000	Inhalable HBCDD: 23 mgm^{-3} Dermal exposure: 840 mg/day Process runs intermittently, exposure occurs <25% of time.	<0.001 (a)
Total Manufacture			∑ EU manufacture	Uncertainty of estimate:	∑ releases (t/y) <0.004,

			(t/y ; uncertainty; trend, incl. shifts between manufacturing processes) t/y varies between years; trend: Likely to have increased between 2005 and 2007 in response to 10% increase in sales in the EU over this period, may reduce in future between of growing consumer awareness of the environmental issues associated with brominated fire retardants plus economic recession	Mean inhalation exposure levels, quite tight range for process workers; exposure control problems at micronising plant, now not operating. EASE model for dermal exposure is not reliable.	uncertainty of estimate: good, low emissions from sites; trends, declining through ongoing control
Import subst. on its own			5580t/y		
Import subst. in preparations			unknown		
Import subst. in articles [2]			unknown		
Import into EU (total)			∑ t/y Unknown: trends: Increasing use between 2003 and 2007		
Export subst. on its own			1882t/y		
Export subst. in preparations			unknown		
Export subst. in articles [1]			unknown		
Export from EU (total)			∑ t/y Unknown; uncertainty: Unknown; trends: Unknown		
Global manufacture			∑ t/y: Unknown; uncertainty: Unknown; trends: Unknown		
Unintentional formation during incineration (EU)	0			**0**	**0**
Unintentional formation in processes (EU)	0			**0**	**0**
Unintentional formation by transformation/degradation (EU)	0			**0**	**0**
Total unintentional formation (EU)				∑ t/y 0; uncertainty: none; trends: flat	∑ t/y 0; uncertainty: none; trends: flat

[1] A list of article types in which the substance is included shall be provided in addition.

[2] In quantitative or geographical terms exact specifications are only required if the number of sites is low. If there are many sites a semi-quantitative or qualitative description of the manufacturing structure and spatial distribution of manufacturing sites (e.g. in which Member States, regions, etc.) may suffice.

3 In case a quantification of releases is not possible a qualitative description of the emission situation at the workplace(s) shall be given and a semi-quantitative estimate of the exposure situation provided (e.g. no exposure – very high exp.).

(a) – air; (ww) – waste water

Table 2: Overview on tasks related to work package 2 (grey shaded fields not relevant)

Uses	**Use Process** (description: narrative and by use descriptor system)	**Amount used** (t/y)	**Number of sites of use** [1] (#)	**Spatial distribution of emission sites** [1]	**Releases to working environment** [3] (t/y)	**Releases to environment** (t/y released to air, wastewater or to waste)
Formulation						
Formulation 1	Production of Expanded Polystyrene (EPS); PROC4 Use in batch and other process (synthesis) where opportunity for exposure arises, Industrial setting	5301	21	I in Austria 2 in Belgium 2 in Czech Republic 1 in Finland 1 in France 4 in Germany 1 in Greece I in Hungary 1 in Italy 4 in Netherlands 1 in Poland 2 in Spain	Process workers: Inhalable HBCDD: 1.2 mgm^{-3} Dermal exposure powder: 17 mg/day Dermal exposure Granules 1.7 mg/day Shift pattern not recorded During weighing Inhalable HBCDD: 7.2mgm^{-3} Dermal exposure powder: 17 mg/day Dermal exposure Granules 1.7 mg/day 15 days per year	0.03 (a) 0.08(ww) 0.33 (sw)
Formulation 2	Production of (XPS) PROC4 Use in batch and other process (synthesis) where opportunity for exposure arises, Industrial setting	5859	28	1 in Austria 1 in Belgium 3 in France 6 in Germany 1 in Greece 1 in Hungary 5 in Italy 1 in Netherlands 1 in Portugal 1 in Serbia	Process workers: Inhalable HBCDD: 0.03 mgm^{-3} Dermal exposure powder: 17 mg/day Dermal exposure Granules 1.7 mg/day Shift rotation results in exposure on 33% of shifts or less.	0.01 (a) 0.08 (ww) 0.01 (sw)

				4 in Spain 1 in Sweden 2 in UK		
Formulation 3	Production of HIPS PROC4 Use in batch and other process (synthesis) where opportunity for exposure arises, Industrial setting	210	3	unknown	Process workers: Inhalable HBCDD: 1.2 mgm^{-3} Dermal exposure powder: 17 mg/day Dermal exposure Granules 1.7 mg/day Small scale, exposure likely to be occasional	included in Formulation 1
Formulation 4	Textile Coating production PROC4 Use in batch and other process (synthesis) where opportunity for exposure arises, Industrial setting	210 (2007 estimate)	16	7 in UK 5 in Belgium 4 in Germany	Process workers: Inhalable HBCDD: 1.35 mgm^{-3} Dermal exposure: 120 mg/day Many other formulations used, exposure likely on <25% of shifts Laboratory staff: Inhalable HBCDD: 0.23 mgm^{-3} Dermal exposure: unknown Many other formulations handled, exposure likely to occur on <25% of shifts	0.001 (a) 0.044 (ww) 0.011 (sw)
∑ Formulation		∑ t/y: 11580; uncertainty: 2006 figures except textile coating; trends: sales increased every year bar	∑#: 47, trend: unknown	Overall geographical pattern; trend: widespread across Europe; increased used in recent years, pressure to reduce in Nordic countries	Uncertainty of estimate: Mean inhalation exposure levels, quite tight range for process workers. EASE model for dermal exposure is not very accurate.	∑ t/y 0.041 (a), 0.060 (ww), 0.35 (sw); uncertainty: :not known; trends not known

		2006 between 2002 and 2007, may be a decline in Nordic countries, economic uncertainty affecting construction and use of insulation				
End uses						
End Use 1	Application of coating to textile PROC10: Roller application or brushing of adhesive and other coating Industrial or non-industrial setting	210 (2007 estimate)	24	15 in Belgium 9 in UK	Process workers: Inhalable HBCDD: 1.35 mgm^{-3} Dermal exposure: 120 mg/day Many other formulations used, exposure likely on <25% of shifts Laboratory staff: Inhalable HBCDD: 0.23 mgm^{-3} Dermal exposure: unknown Many other formulations handled, exposure likely to occur on <25% of shifts	<0.001 (a) 1.1 (ww) 0.28 (sw)
End Use 2	Production of EPS articles PROC4 Use in batch and other process (synthesis) where opportunity for exposure arises,	5301	28	across Europe	Process workers: Inhalable HBCDD: 1.2 mgm^{-3} Dermal exposure powder: 17 mg/day Dermal exposure Granules	0.16 (a) 0.012 (ww) 0.03 (sw)

	Industrial setting				1.7 mg/day Shift pattern not recorded	
End use 3	Production of HIPS articles PROC4 Use in batch and other process (synthesis) where opportunity for exposure arises, Industrial setting	210	unknown	unknown	Process workers: Inhalable HBCDD: 1.2 mgm^{-3} Dermal exposure powder: 17 mg/day Dermal exposure Granules 1.7 mg/day Small scale, exposure likely to be occasional.	0.006 (a) 0.005 (ww) 0.001 (sw)
End use 4	Production of XPS article PROC4 Use in batch and other process (synthesis) where opportunity for exposure arises, Industrial setting s	5859	21	unknown	Process workers: Inhalable HBCDD: 0.08 mgm^{-3} Dermal exposure powder: 17 mg/day Dermal exposure Granules 1.7 mg/day Shift rotation results in exposure on 33% of shifts or less.	0.14(a) 0.06 (ww) 0.02 (sw)
End Use 5	Use of Insulation Boards in construction (XPS + EPS) PROC21: Low energy manipulation of substances bound in materials and/or articles PROC23: High (mechanical) energy work-up of substances bound in materials and/or articles	Already included above	1000s	across Europe	Inhalable HBCDD: <0.1 mgm^{-3} Dermal Exposure: <1.7mg/day Exposure pattern unknown	0.24 (a) 0.24 (sw)
∑ End Uses		∑ t/y11580; uncertainty:	∑# 1000s, trend not	Overall geographical pattern across Europe; trend: trend	Uncertainty of estimate: Mean inhalation exposure	∑ t/y 0.53 (a), 1.14 (ww), 0.56 (sw); uncertainty: majority of

		2007 estimate for textile coating, 2006 figures for other uses, excludes imports of insulation boards; sales of HBCDD for EPS and XPS increased between 2002 and 2006, Helcon countries discouraging use	known	increased use over recent years; Pressure to reduce use in the Helcon countries	levels, quite tight range for process workers. Inhalation exposure to HBCDD on construction sites assumes dust concentrations arising from the board are less than 10 mgm^{-3} (likely). EASE model for dermal exposure is not reliable.	release is from textile coating; excludes disposal of all materials; trends: assumed increase with increasing production.
Consumer use						
Substance in articles[2] (service life of articles)		C12.1: Constructional articles and building material for indoor use: wall construction material ceramic, metal, plastic and wood construction material, insulating material C12.2: Constructional articles and building	not appropriate	textiles used mainly in UK and Ireland		0.05 (a) 0.02 (ww) 0.005 (sw)

		material for outdoor use: wall construction material, road surface material, ceramic, metal, plastic and wood construction material, insulating material AC5: Fabrics, textiles and apparel: bedding and clothing; curtains, upholstery, carpeting/ flooring, rugs AC3: Electrical and electronic products, e.g. computers, office equipment, video and audio recording, communication equipment; Household appliances				

		(white ware)				
Substance in preparations						
∑ consumer use of subst. in articles and preparations		∑ t/y not meaningful as most uses of HBCDD have a lifetime of 10 or more years; uncertainty: huge; trends: amount of HBCDD in consumers' premises increases every year as insulation is installed furniture replaced etc				∑ t/y 0.05 (a), 0.12 (ww), 0.03 (sw); uncertainty: excludes disposal, EU15 not EU27; trends unknown

1 In quantitative or geographical terms exact specifications are only required if the number of sites is low. If there are many sites a semi-quantitative or qualitative description of the use structure and spatial distribution of sites of release (e.g. in which Member States, regions, etc.) may suffice.

2 A list of article types with the substance included and used by consumers shall be provided as well.

3 In case a quantification of releases is not possible a qualitative description of the emission situation at the workplace(s) shall be given and a semi-quantitative estimate of the exposure situation provided (e.g. no exposure – very high exp.).

(a) – air; (ww) – waste water; (sw) – surface water

Table 3: Overview of quantitative information requested at Member State level for individual years. Production data for individual member states is not available

YEAR 2000-2004	**Manufacturing** (t/y)	**Manufacturing** # sites	**Formulation** (t/y)	**Formulation** # sites	**Use 1** (t/y)	**Use 1** # sites	**Use 2** (t/y)	**Use 2** # sites
Member state								
Austria								
Belgium								
…								
Total	**6000**	**1**	6382	>50	**1050**	**24**	**3392**	**100s**

YEAR 2000-2004	**Use 3** (t/y)	**Use 3** # sites	**Use 4** (t/y)	**Use 4** # sites	**Use 5** (t/y)	**Use 5** # sites		
Member state								
Austria								
Belgium								
…								
Total	**210**	**unknown**	**4962**	**35**	**~7500**	**1000s**		

YEAR 2006	**Manufacturing** (t/y)	**Manufacturing** # sites	**Formulation** (t/y)	**Formulation** # sites	**Use 1** (t/y)	**Use 1** # sites	**Use 2** (t/y)	**Use 2** # sites
Member state								
Austria				2				1
Belgium				3				2
Czech Republic				2				2
Finland				1				1
France				4				1
Germany				10				4
Greece				2				1
Hungary				2				1
Italy				6				1
Netherlands	6000	1		5				4
Norway				1				
Poland				1				1
Portugal				1				
Spain				6				2
Sweden				1				
United Kingdom				2				
Total	**6000**	**1**	11580	49	**210**	**24**	**5301**	**21**

YEAR 2006	**Use 3** (t/y)	**Use 3** # sites	**Use 4** (t/y)	**Use 4** # sites	**Use 5** (t/y)	**Use 5** # sites		
Member state								
Austria				1				
Belgium				1				
Czech Republic								
Finland								
France				3				
Germany				6				
Greece				1				
Hungary				1				
Italy				5				
Netherlands				1				
Norway				1				
Poland								
Portugal				1				
Spain				4				
Sweden				1				
United Kingdom				2				
Total	**210**	**unknown**	**5859**	**28**	**11000**	**1000s**		

ANNEX 2: