3

STOCKHOLM CONVENTION

GUIDANCE ON ALTERNATIVES TO DECABROMODIPHENYL ETHER (decaBDE)

2021

UN environment programme

STOCKHOLM CONVENTION

3

STOCKHOLM CONVENTION

GUIDANCE ON ALTERNATIVES TO DECABROMODIPHENYL ETHER (decaBDE)

2021

UN environment programme

STOCKHOLM CONVENTION

ACKNOWLEDGEMENT

The European Union, the Governments of Germany and Sweden are gratefully acknowledged for providing the necessary funding that made the production of this publication possible.

The feedback from Parties and observers to the Stockholm Convention on Persistent Organic Pollutants is highly appreciated.

Recommended citation: UNEP (2021). Guidance on alternatives to decabromodiphenyl ether (decaBDE). Revised from document UNEP/POPS/COP.9/INF/20. Secretariat of the Basel, Rotterdam and Stockholm conventions, United Nations Environment Programme, Geneva.

Author: Roland Weber, POPs Environmental Consulting

Project manager: Kei Ohno, Secretariat of the Basel, Rotterdam and Stockholm conventions

Contact information:

Secretariat of the Basel, Rotterdam and Stockholm conventions

Office address: 11-13, Chemin des Anémones - 1219 Châtelaine, Switzerland

Postal address: Avenue de la Paix 8-14, 1211 Genève 10, Switzerland

Tel.: +41 22 917 8271

Email: brs@un.org

CONTENTS

LIST OF ACRONYMS AND ABBREVIATIONS

ATH	Aluminum trihydroxide
ATO	Antimony oxide
BDP/BAPP	Bisphenol A bis(diphenyl phosphate)
BFR	Brominated flame retardant
BSEF	Bromine Science and Environmental Forum
C-decaBDE	Commercial decabromodipheyl ether
DBDPE	Decabromodiphenyl ethane
DecaBDE	Decabromodiphenyl ether
DEFRA	Department for Environment, Food and Rural Affairs
DME	Danish Ministry of the Environment
EBTBP	Ethylene bis(tetrabromophthalimide)
ECHA	European Chemicals Agency
EEE	Electronic and electrical equipment
EPA	Environmental Protection Agency
EU	European Union
EVA	Ethylene-vinyl acetate
IEC	International Electrotechnical Commission
LCSP	Lowell Center for Sustainable Production
MDH	Magnesium hydroxide
NTP	National Toxicology Program
PA	Polyamide/nylon
PAEK	Polyaryletherketone
PES	Polyethersulphone
ppm	Parts per million
PVC	Polyvinyl chloride
PBTE	Poly(butylene terephthalate)
RDP	Resorcinol bis(diphenylphosphate)
RPA	Risk and Policy Analysts
TBBPA	Tetrabromobisphenol A bis (2,3-dibromopropyl ether)
TDCPP	Tris(1,3-dichloro-2-propyl) phosphate
TPP	Triphenyl phosphate
UL	Underwriters' Laboratories Inc.
UNEP	United Nations Environment Programme

1. INTRODUCTION

1.1 LISTING OF DECABROMODIPHENYL ETHER IN ANNEX A

In 2017, by decision SC-8/10, the Conference of the Parties to the Stockholm Convention on Persistent Organic Pollutants (POPs) amended Annex A to the Convention to list decabromodiphenyl ether (BDE-209) present in commercial decabromodiphenyl ether (c-decaBDE) with specific exemptions (Table 1), i.e. time limited exemption.

Like all POPs, this chemical possesses toxic properties, resist degradation, and bioaccumulate. It is transported through air, water and migratory species, across international boundaries and deposited far from their place of release, where they accumulate in terrestrial and aquatic ecosystems. Information risks of decaBDE can be found in the risk profile of decaBDE (UNEP/POPS/POPRC.10/10/Add.2 and UNEP/POPS/POPRC.11/INF/5).[1]

All uses for decaBDE other than those listed as specific exemptions are prohibited because alternatives are readily available. Information on alternatives to decaBDE for the uses not allowed as specific exemptions can be found in the risk management evaluation of decaBDE (UNEP/POPS/POPRC.11/10/Add.1 and UNEP/POPS/POPRC.11/INF/6).[2]

C-decaBDE is a general-purpose additive flame retardant compatible with a wide variety of materials. Applications include plastics/polymers/composites, textiles, adhesives, sealants, coatings and inks. End uses in plastics/polymers include housings of computers and TV sets, wires and cables, pipes and carpets. BDE-209 is also found in products made from recycled plastics, including food contact materials. In the textile sector, c-decaBDE is used to treat a wide range of synthetic, blended and natural fibres. Main end uses include upholstery, window blinds, curtains, mattress textiles, tentage (e.g. military tents and textiles, commercial marquees, tents, canvasses) and transportation (e.g. interior fabrics in cars, rail passenger rolling stock and aircraft).

Globally up to 90% of c-decaBDE ends up in plastics, primarily in electronics, while the remaining ends up in coated textiles, upholstered furniture and mattresses.

Table 1: Specific exemptions for decabromodiphenyl ether (BDE-209) present in commercial decabromodiphenyl ether

Chemical	Activity	Specific exemption
Decabromodiphenyl ether (BDE-209) present in commercial decabromodiphenyl ether (CAS No: 1163-19-5)	Production	As allowed for the Parties listed in the Register
	Use	In accordance with Part IX of Annex A: • Parts for use in vehicles specified in paragraph 2 of Part IX of Annex A • Aircraft for which type approval has been applied for before December 2018 and has been received before December 2022 and spare parts for those aircraft • Textile products that require anti-flammable characteristics, excluding clothing and toys • Additives in plastic housings and parts used for heating home appliances, irons, fans, immersion heaters that contain or are in direct contact with electrical parts or are required to comply with fire retardancy standards, at concentrations lower than 10 per cent by weight of the part • Polyurethane foam for building insulation

1 http://chm.pops.int/tabid/5985/Default.aspx; http://chm.pops.int/tabid/3778/Default.aspx.
2 http://chm.pops.int/tabid/5985/Default.aspx; http://chm.pops.int/tabid/4558/Default.aspx.

Specific exemptions for parts for use in vehicles may be available for the production and use of decaBDE limited as presented in Table 2 below.

The specific exemptions for spare parts for aircraft for which type approval has been applied for before December 2018 and has been received before December 2022 shall expire at the end of the service life of those aircraft.

Table 2: Specific exemptions for parts for use in vehicles

Specific exemption	Application	Expire date
(a) Parts for use in legacy vehicles, defined as vehicles that have ceased mass production, and with such parts falling into one or more of the following categories:	(i) Powertrain and under-hood applications such as battery mass wires, battery interconnection wires, mobile air-conditioning (MAC) pipes, powertrains, exhaust manifold bushings, under-hood insulation, wiring and harness under hood (engine wiring, etc.), speed sensors, hoses, fan modules and knock sensors; (ii) Fuel system applications such as fuel hoses, fuel tanks and fuel tanks under body; (iii) Pyrotechnical devices and applications affected by pyrotechnical devices such as air bag ignition cables, seat covers/fabrics (only if airbag relevant) and airbags (front and side); (iv) Suspension and interior applications such as trim components, acoustic material and seat belts.	At the end of the service life of legacy vehicles or in 2036, whichever comes earlier
(b) Parts in vehicles specified in paragraphs (a) (i)–(iv) above and those falling into one or more of the following categories:	(i) Reinforced plastics (instrument panels and interior trim); (ii) Under the hood or dash (terminal/fuse blocks, higher-amperage wires and cable jacketing (spark plug wires); (iii) Electric and electronic equipment (battery cases and battery trays, engine control electrical connectors, components of radio disks, navigation satellite systems, global positioning systems and computer systems); (iv) Fabric such as rear decks, upholstery, headliners, automobile seats, head rests, sun visors, trim panels, carpets.	At the end of the service life of vehicles or in 2036, whichever comes earlier

1.2 OBJECTIVE OF THE GUIDANCE

This guidance document compiles chemical alternatives and non-chemical alternatives to decaBDE, mainly for the uses listed as specific exemptions in Annex A to the Convention (Table 1). Parties may wish to consider the information available in this guidance when phasing-out the use of decaBDE.

The guidance was prepared based on the information contained in the documents adopted by the POPs Review Committee (UNEP/POPS/POPRC.11/10/Add.1 and UNEP/POPS/POPRC.11/INF/6). Other reports and information on alternatives to c-decaBDE have also been taken into account.

2. ALTERNATIVES TO decaBDE

There are several assessments of alternatives to c-decaBDE/BDE-209 focusing on various chemicals with flame retardant properties. The first step of such assessment could be to determine whether flame retardancy is needed, and if so, how it can be achieved without adverse environmental and human health consequences, before considering chemical substitutes (UNEP/POPS/POPRC.11/10/Add.1). Alternative techniques such as using inherently fire-resistant materials, adding fire-resistant barriers, or completely redesigning the product can greatly improve fire safety (ECHA, 2015; USEPA, 2014). Alternatives that eliminate the need for chemical flame retardants through material substitution or design while meeting relevant fire safety standards and performance requirements are preferable, especially when they include chemicals of low toxicity and contain recyclable or compostable materials (UNEP/POPS/POPRC.11/INF/6).

Furthermore, some fire safety requirements leading to the use of flame retardants may need to be re-evaluated. For instance, the state of California, whose Technical Bulletin 117 had led to added flame retardants in furniture for decades, passed Assembly Bill 2998 in September 2018 (California, 2018). The Assembly Bill 2998 states that "The State of California has found that flame retardant chemicals are not needed to provide fire safety," in a range of applications and bans the sale or distribution in commerce in California on or after 1 January 2020, of any "not previously owned juvenile products, mattresses, or upholstered furniture" containing flame retardants that are "halogenated, organophosphorus, organonitrogen, or nanoscale" chemicals at levels above 1,000 ppm.

In some cases, however, a chemical substitute for decaBDE is needed. The USEPA and ECHA have published comprehensive assessments of 29 and 13, respectively, chemical alternatives to c-decaBDE (USEPA, 2014; ECHA, 2015). Other brominated flame retardants (BFRs) could act as drop-in replacements for many of the known c-decaBDE applications (ECHA, 2015; USEPA, 2014). Viable non-halogenated flame retardants and polymer combinations have also been identified as alternatives for most c-decaBDE uses, and some may even have better performance than c-decaBDE (ENFIRO, 2013; Table 8, UNEP/POPS/POPRC.11/INF/6). However, while chemical alternatives are readily available for all uses of c-decaBDE, some of them also have problematic hazard profiles (ECHA, 2015; USEPA, 2014).

2.1 PLASTICS (PARTS FOR USE IN VEHICLES AND IN AIRCRAFT, ADDITIVES IN PLASTIC HOUSINGS AND PARTS USED FOR HEATING HOME APPLIANCES, IRONS, FANS, IMMERSION HEATERS)

2.1.1 Background

Plastics and electronics account for approximately 90% of the use of c-decaBDE. Some plastics must comply with flammability tests such as those established by the International Electrotechnical Commission (IEC) or the Underwriters' Laboratories Inc. (KemI, 2005). However, although these fire safety regulations are mandatory, none of them require the use of specific flame retardants. It is up to the manufacturers to decide how to achieve compliance.

In the transportation sector, c-decaBDE was used in plastics for electronic and electrical equipment (EEE), reinforced plastics, under the hood, and in inner parts, as well as in the interiors of cars. Most of the fire-retarded plastics used in vehicles are found in the engine compartment and are often polyamides (PA). The firewall between the engine and the cabin is also fire-retarded.

The aviation industry has been using c-decaBDE in electrical wiring and cables, interior components, and EEE components in older airplanes and spacecrafts.

The automotive and aviation industry are phasing out c-decaBDE. However, for service and some legacy spare parts for use in articles already in use, as well as for aircrafts currently in production under existing type certificates require continuous production and use for a certain period (UNEP/POPS/POPRC.11/10/Add.1).

An assessment by the EU (ECHA, 2015) identified various alternative techniques that could replace c-decaBDE in plastics, including chemical alternatives, inherently fire-resistant materials, intumescent systems, nanocomposites, expandable graphite, smoke suppressants, polymer blends, and product redesign. These alternatives techniques are described in detail in Table 14 of document UNEP/POPS/POPRC.11/INF/6.

2.1.2 Alternative materials

Metal or inherently fire-resistant plastics can be used as alternative materials in certain electronic products. New inherently fire-resistant materials are increasingly being mentioned in the literature or on commercial websites, often promoted as replacements for c-decaBDE (ECHA, 2012; DEFRA, 2010; PR Newswire, 2010; UNEP/POPS/POPRC.11/10/Add.1).

The following plastics are inherently fire-resistant and could replace polymers typically treated with c-decaBDE such as poly(butylene terephthalate) (PBTE) and polyamide/nylon (PA) (DME, 2006):

(c) Halogen-free polyketone;

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

Polymers that char, such as polyimides, polyaramides, liquid crystal polyesters, polyphenylene sulphide, polyarylenes, and many thermosets, also tend to have greater fire resistance.

Halogenated polymers such as PVC also have flame retardant properties because they release halogen radicals during combustion. The effect is often enhanced by the addition of synergists such as ATO to halogenated polymer blends. However, like brominated flame retardants, PVC can form dioxins and acids upon combustion, and is therefore not a preferred alternative material (Blomqvist et al., 2007).

2.1.3 Fire barriers

Using fire-resistant metal barriers to separate or isolate the most flammable parts from the rest of the product can eliminate the need for flame retardants such as c-decaBDE (LCSP, 2005).

2.1.4 Intumescent systems

In plastics, like in textiles, fire safety may be achieved via the use of intumescent systems (Klif, 2011; USEPA, 2014). Intumescence is the formation of a foamed char, which acts as heat insulation. An intumescent system is generally a combination of a source of carbon to build up char, an acid-generating compound, and a decomposing compound that generates blowing gases to produce foamed char (Weil and Levchik, 2009). This foam attains a thickness of 10 to 100 times that of the originally applied coating and insulates the substrate material through its low thermal conductivity. This makes intumescent systems efficient at reducing both flammability and exposure to toxic gases and fumes (KemI, 2006). Intumescent systems include use of expandable graphite impregnated foams, surface treatments, and some barrier technologies (Klif, 2011).

2.1.5 Product redesign

Electronic and electrical equipment can be redesigned to eliminate or reduce the need for chemical flame retardants. Possible redesign strategies include:

(a) Separating the high-voltage components that need greater ignition protection from the low-voltage components;

(b) Reducing the operating voltage requirements, therefore reducing the need for fire-resistant enclosure materials;

(c) Separating the power supply from the product, which reduces the fire-retardancy requirements of the electronic enclosure;

(d) Shielding power supplies with metal to eliminate the need for additive flame retardants.

2.1.6 Chemical alternatives

Flame retardants ideal for plastics must:

(a) Not alter the mechanical properties of the plastic;

(b) Not change the colour of the plastic;

(c) Not cause corrosion;

(d) Have good light stability;

(e) Resist aging and hydrolysis;

(f) Begin their thermal behaviour before the thermal decomposition of the plastic;

(g) Not have harmful physiological effects;

(h) Not emit toxic gases, or at least emit them at low levels;

(i) Be as inexpensive as possible – although function is more important than price for engineering polymers, and typically not the most important factor for alternatives selection (KemI, 2005).

According to the EU restriction proposal, eight chemical flame retardants appear to be possible substitutes for c-decaBDE in plastic polymers (ECHA, 2015):

(a) Decabromodiphenyl ethane (DBDPE);

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

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

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

(e) Magnesium hydroxide (MDH);

(f) Triphenyl phosphate (TPP);

(g) Aluminium trihydroxide (ATH);

(h) Red phosphorous.

2.2 TEXTILE PRODUCTS THAT REQUIRE ANTI-FLAMMABLE CHARACTERISTICS

2.2.1 Background

C-decaBDE has traditionally been applied to textiles as a back-coating in combination with antimony oxide (ATO) as a synergist (LCSP, 2005). C-decaBDE is first mixed with ATO to form an aqueous dispersion, which is then mixed with a polymer emulsion containing for instance natural or synthetic rubber, ethylene-vinyl acetate (EVA), styrene-butadiene copolymer, or polyvinyl chloride (PVC) (ECHA, 2012). The c-decaBDE-ATO mixture can account for 18 to 27% of the total product weight (LCSP, 2005). Lighter fabrics usually require higher flame retardant loadings. Fire-resistant back-coatings are used on a wide range of fabrics, including polyamide/nylon, polypropylene, acrylics, and blends such as nylon–polyester.

In the US, c-decaBDE is used in textile applications for transportation (e.g., public transit buses, trains, aviation, ships); draperies for public occupational spaces; furniture for high-risk occupational areas (e.g., nursing homes, hospitals, prisons, hotels); military tarps, tents, and protective clothing – but is not used in consumer clothing (LCSP, 2005; BSEF, 2018; USEPA, 2014). However, the use of c-decaBDE in residential upholstery and mattresses is no longer allowed in several states in the US (LCSP, 2015), and the sale of "not previously owned juvenile products, mattresses, or upholstered furniture" containing flame retardants that are "halogenated, organophosporus, organonitrogen, or nanoscale" chemicals at levels above 1,000 ppm is banned in California as of January 1, 2020 (California, 2018).

In the EU, c-decaBDE is used in domestic draperies and furniture (in foams, fillings, and back-coatings), predominantly in countries with certain fire safety standards such as the UK (ECHA, 2015). In Japan, vehicle seats accounts for 60% of the c-decaBDE use, while an additional 15% is reportedly used for other textile applications (Sakai et al., 2006).

Substitution of c-decaBDE in textiles is not straightforward due to the complexity of the end-products and the wide array of possible substitution approaches. These approaches include alternative flame retardants, alternative fibres, and barrier layers.

2.2.2 Alternative fibres

Natural fibres are easier to chemically flame retard than synthetics. Several non-halogenated c-decaBDE chemical substitutes are available for natural cellulose or protein fibres such as cotton, wool, rayon (viscose, modal, and lyocell), and linen, including:

(a) Ammonium polyphosphates;

(b) Dimethylphosphono (N-methylol) propionamide;

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

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

Furthermore, some natural materials like leather and wool have inherently fire-resistant properties and, depending on the thickness of the weave, can meet fire safety requirements without additional chemical treatment (Klif, 2011; Weber et al. 2018).

Nonwoven fabrics are also inherently fire-resistant, as are a number of synthetic fibres including aramids, viscose, novoloid, polyamides, melamine, and polyester. Some of these fire-resistant fibres, such as polyhaloalkenes, contain PVC, vinyl bromide, and other halogens, while others, such as polyaramides and melamine, are halogen-free (LCSP, 2005; UNEP/POPS/POPRC.11/INF/6).

Some fabrics for upholstery, mattresses, and drapery are made from blends of inherently fire-resistant fibres with fibres of lower flame performance. For instance, cotton is usually blended with polyester ('poly-cotton' blend), nylon, or melamine to reduce its flammability (DEFRA, 2010).

2.2.3 Fire barriers

Fire-resistant barrier layers can be used between the surface fabric and the interior foam core in furniture and mattresses. They fully encapsulate the interior materials and must be combined with fire-resistant border seams, tape, and threads (LCSP, 2005). Fire barriers are made from inherently fire-resistant fibres such as wool, para aramids, melamines, modacrylics, or glass fibre, without the need for flame retardant chemicals. Moreover, many of these fibres are made from non-halogen materials. Some barriers can also be made from blends of inexpensive fibres and expensive inherently fire-resistant fibres. In addition to fibre blends, many manufacturers use cotton-batting materials treated with boric acid. Plastic films have also been used as barriers, especially films made of inherently fire-resistant plastics such as neoprene (polychloroprene) (LCSP, 2005).

2.2.4 Intumescent systems

In textiles, like in plastics, fire safety may also be achieved via the use of intumescent systems (Klif, 2011; USEPA, 2014). Intumescence is the formation of a foamed char, which acts as heat insulation. An intumescent system is generally a combination of a source of carbon to build up char, an acid-generating compound, and a decomposing compound that generates blowing gases to produce foamed char (Weil and Levchik, 2009). This foam attains a thickness of 10 to 100 times that of the originally applied coating and insulates the substrate material through its low thermal conductivity. This makes intumescent systems efficient at reducing both flammability and exposure to toxic gases and fumes (Keml, 2006). Intumescent systems include use of expandable graphite impregnated foams, surface treatments, and some barrier technologies (Klif, 2011).

2.2.5 Chemical alternatives

The following seven substances were identified as the most likely chemical alternatives to the use of c-decaBDE in textiles (ECHA, 2015):

(a) Aluminum trihydroxide (ATH);

(b) Magnesium hydroxide (MDH);

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

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

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

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

(g) Red phosphorous;

(h) Decabromodiphenyl ethane (DBDPE).

Co-polymerization, i.e., including an additive in the fibre melt spinning process, makes the flame-retardant chemical a physical part of the fibre matrix. The most common flame retardant for polyester is polyethylene terephthalate with built-in phosphorus on the polyester backbone. This modified polyester is used in the majority of textile applications, is wash resistant, and is thought to be a good substitute for c-decaBDE-ATO. Polyester accounts for 30% of the world fibre production, with applications including clothing and draperies.

2.3 POLYURETHANE FOAM FOR BUILDING INSULATION

2.3.1 Background

Rigid polyurethane foam has good insulating properties that make it suitable for insulation of walls and roofs in new buildings and when buildings are renovated.

Sprayed polyurethane foam provides weatherproof sealants, forms a seamless layer of insulation, fills gaps and seams during application, and covers irregular, hard-to-insulate shapes (American Chemical Council 2018). Spray polyurethane foam (SPF) insulation can be categorized into two different types: light-density open-cell spray foam insulation and medium-density closed-cell spray foam insulation. Both types of SPF are thermoset cellular plastics. Closed cell spray polyurethane foam insulation forms an air barrier and moisture barrier.

2.3.2 Resin/Material substitution

A variety of insulation materials are used in buildings, each having some advantages for specific applications determining its use, and many with general application (Secretariat of the Stockholm Convention 2017). In terms of market volumes major insulation alternatives are EPS/XPS, mineral wool, and fibre glass wool, but a number of other insulation materials are used to some extent.

Expanded and extruded polystyrene (EPS/XPS)

Expanded and extruded polystyrene (EPS/XPS) are major insulation used in a variety of installations for the entire building envelope.

Expanded polystyrene (EPS) foam is a closed-cell insulation that's manufactured by "expanding" a polystyrene polymer. Extruded polystyrene (XPS) foam is a rigid insulation that's also formed with polystyrene polymer but manufactured using an extrusion process.

Stone wool

Stone wool is made from volcanic rock, typically basalt or dolomite, an increasing proportion of which is recycled material in the form of briquettes. Slag wool is made from blast furnace slag (waste). The stone wool is a subgroup of the mineral wool together with glass wool. Over the last decade, glass wool, rock (stone) wool and slag wool have together met just over half of the world demand for insulation.

The structure and density of the product can be adapted to its precise final usage. Inorganic rock or slag is the main components (typically 98%) of stone wool. The remaining 2% organic content is generally a thermosetting resin binder (an adhesive), usually phenol formaldehyde and a little mineral oil (Secretariat of the Stockholm Convention 2017).

Glass wool (fibre glass insulation)

For glass wool the raw materials are sand, limestone and soda ash, as well as recycled off cuts from the production process. The glass wool is a subgroup of the mineral wool.

Small quantities of binding agents are added to the fibres. Glass wool products usually contain 95% to 96% inorganic material (Eurima 2018).

Phenolic foams

Phenolic foam insulation is made by combining phenol-formaldehyde resin with a foaming agent. In the process phenol is polymerized by substituting formaldehyde on the phenol's aromatic ring via a condensation reaction and a rigid thermoset material is formed (Secretariat of the Stockholm Convention 2017).

Natural fibre-based insulation materials

Various modern insulation materials are based on natural fibres, primarily plant fibres but also sheep wool. Some of these have been known for centuries but have got a renaissance over the last decades with the growing interest for environment friendly building techniques. They are available as loose insulation fill, as insulation batts or/and as rolls. A number of the other natural fibre-based insulation materials have been considered as alternatives (Secretariat of the Stockholm Convention 2017).

2.3.3 Chemical Alternatives

The EU restriction proposal for c-decaBDE identified the following six alternative flame-retardant chemicals for applications such as in polyurethane foam for building insulation:

(a) Magnesium hydroxide (MDH);

(b) Aluminum trihydroxide (ATH);

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

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

(e) Red phosphorous;

(f) Decabromodiphenyl ethane (DBDPE).

REFERENCES

American Chemical Council (2018) Introduction to Polyurethanes: Polyurethane in Building and Construction. Available at: https://polyurethane.americanchemistry.com/polyurethane/Introduction-to-Polyurethanes/Applications/Polyurethane-in-Building-and-Construction/

Apple Inc. (2018). Available at: http://www.apple.com/environment/toxins/ [Accessed 9 December 2018].

Blomqvist P, Andersson P and Simonson M (2007). Fire emissions of organics into the atmosphere. Fire Technology 43, 213-231.

BSEF, Bromine Science and Environmental Forum (2018). About Bromine. Available at: http://www.bsef.com/. [Accessed 9 December 2018].

California (2018). Assembly Bill No. 2998 Consumer products: flame retardant materials. Chapter 924. Available at: https://leginfo.legislature.ca.gov/faces/billNavClient.xhtml?bill_id=201720180AB2998 [Accessed 9 December 2018].

DEFRA, Department for Environment, Food and Rural Affairs (2010). Fire Retardant Technologies: safe products with optimised environmental hazard and risk performance. Authors: GnoSys UK Ltd, University of Bolton, and Oakdene Hollins Ltd. Available at: randd.defra.gov.uk/Document.aspx?Document=EV0432_9845_FRP.pdf [Accessed 9 December 2018].

DME, Danish Ministry of the Environment (2006). Deca-BDE and Alternatives in Electrical and Electronic Equipment, Environmental project No. 1141/2006, pp. 1-93. Authors: Lassen C et al.

ECHA, European Chemicals Agency (2012). Annex XV dossier. Proposal for Identification of a PBT/vPvB Substance. Bis(pentabromophenyl)ether (decabromodiphenyl ether; decaBDE). July 2012final. Submitted by the United Kingdom, August 2012. Available at: http://echa.europa.eu/documents/10162/13638/SVHC_AXVREP_pub_EC_214_604_9_decabromodiphenylether_en.pdf [Accessed 9 December 2018].

ECHA, European Chemicals Agency (2015). Committee for Risk Assessment (RAC) and Committee for Socio-economic Analysis (SEAC). Background document to the Opinion on the Annex XV dossier proposing restrictions on Bis(pentabromophenyl) ether. ECHA/RAC/RES-O-0000006155-77-01/D. Available at: https://echa.europa.eu/documents/10162/2c27ddcc-dd0c-49e3-85ba-fa64b0813775 [Accessed 9 December 2018].

ENFIRO (2013). Final Report Summary - ENFIRO (Life Cycle Assessment of Environment-compatible Flame Retardants (Prototypical case study)). Available at: https://cordis.europa.eu/result/rcn/56829_en.html [Accessed 9 December 2018].

Eurima (2018). Stone wool and glass wool applications and Mineral Wool Composition. European Insulation Manufacturers Association. http://www.eurima.org [Accessed 10 December 2018].

KemI, Swedish Chemical Agency (2005). Survey and technical assessment of alternatives to Decabromodipenyl ether (decaBDE) in plastics. Authors: Posner S, Börås L. Report No 1/05, pp 1-34. Available at: https://www.kemi.se/global/rapporter/2005/rapport-1-05.pdf [Accessed 9 December 2018].

KemI, Swedish Chemical Agency (2006). Survey and technical assessment of alternatives to TBBPA and HBCDD. Report 1/06. Author: Posner, pp 1-43. Available at: https://www.kemi.se/global/pm/2006/pm-1-06.pdf [Accessed 9 December 2018].

Klif, Climate and Pollution Agency Norway (2008). Current State of Knowledge and Monitoring requirements. Emerging "new" brominated flame retardants in flame retarded products and the environment. Report TA-2462/2008. Authors: Harju M et al. Available at: http://www.miljodirektoratet.no/old/klif/publikasjoner/2462/ta2462.pdf [Accessed 9 December 2018].

Klif, Climate and Pollution Agency Norway (2011). Exploration of management options for hexabromocyclododecane. Report to the 8th meeting of the UNECE Task Force on Persistent Organic Pollutants, Montreal 18-20 May 2010 (updated 18 August 2010). Report TA-2818/2011. Authors: Posner S, Roos S, Olsson E, Swerea IVF AB pp 1-84. Available at: http://www.miljodirektoratet.no/old/klif/publikasjoner/2818/ta2818.pdf [Accessed 9 December 2018].

LCSP, Lowell Center for Sustainable Production (2005). Decabromodiphenyl ether: An investigation of non-halogen substitutes in electronic enclosure and textile applications. Prepared by Pure Strategies, Inc. Available at: http://www.sustainableproduction.org/downloads/DecaBDESubstitutesFinal4-15-05.pdf [Accessed 9 December 2018].

LCSP, Lowell Center for Sustainable Production (2009). A new way of thinking: The Lowell Center Framework for Sustainable Products. University of Massachusetts Lowell. Available at: http://www.sustainableproduction.org/downloads/LowellCenterFrameworkforSustainableProducts11-09.09.pdf [Accessed 9 December 2018].

LCSP, Lowell Center for Sustainable Production (2015). US State-level Chemicals Policy Database. Available at: http://www.chemicalspolicy.org/chemicalspolicy.us.state.database.php [Accessed 9 December 2018].

Levchik, S. (2010). Uses of Decabromodiphenyl Oxide (DecaBDE) Flammability Standards Design for the Environment Kick Off Meeting, Crystal City, VA.

New York State Department of Health (2013) Report of the New York State Task Force on Flame Retardant Safety Available at: http://www.health.ny.gov/environmental/investigations/flame/docs/report.pdf [Accessed 9 December 2018].

NTP, National Toxicology Program (1990). Final Report on the Reproductive Toxicity of Boric Acid (CAS NO. 10043-35-3) in CD-1 Swiss Mice. NTP Report no.90-150.

PR Newswire, 2010. ICL-IP Launches Polyquel™ Eco-Friendly Polymeric Flame Retardants. Available at: http://www.prnewswire.com/news-releases/icl-ip-launches-polyqueltm-eco-friendly-polymeric-flame-retardants-93928309.html [Accessed 9 December 2018].

RPA, Risk and Policy Analysts (2014). Multiple Framework Contract with Re-opening of competition for Scientific Services for ECHA. Reference: ECHA/2011/01 Service Request SR 14: Support to an Annex XV Dossier on Bis-(pentabromophenyl) ether (DecaBDE). Authors: Georgalas B, Sanchez A, Zarogiannis P. Available at: http://echa.europa.eu/documents/10162/13641/annex_xvi_consultant_report_decabde_en.pdf [Accessed 9 December 2018].

Sakai SI, Hirai Y, Aizawa H, Ota S, Muroishi Y (2006). Emission inventory of deca-brominated diphenyl ether (DBDE) in Japan. J. Mater. Cycles Waste Manage. 8:56–62.

Secretariat of the Stockholm Convention (2017). Draft Guidance on Best Available Techniques (BAT) and Best Environmental Practices (BEP) for the production and use of hexabromocyclododecane (HBCD) under the Stockholm Convention. Draft January 2017.

USEPA, United States Environmental Protection Agency (2014). An alternatives assessment for the flame retardant decabromodiphenyl ether (decaBDE). Final Report. Available at: https://www.epa.gov/sites/production/files/2014-05/documents/decabde_final.pdf [Accessed 9 December 2018].

UNEP/POPS/POPRC.11/INF/6. Supporting information related to the draft risk management evaluation on decabromodiphenyl ether (commercial mixture, c-decaBDE).

UNEP/POPS/POPRC.11/10/Add.1. Risk management evaluation on decabromodiphenyl ether (commercial mixture, c-decaBDE).

UNEP (2017) Report of the Conference of the Parties to the Stockholm Convention on Persistent Organic Pollutants on the work of its eighth meeting. UNEP/POPS/COP.8/32.

Weber R, Fantke P, Ben Hamouda A, Mahjoub B (2018) 20 Case Studies on How to prevent the use of toxic chemicals frequently found in the Mediterranean Region. https://www.switchmed.eu/e-library/20-case-studies-to-prevent-the-use-of-toxic-chemicals-frequently-found-in-the-mediterranean-region [Accessed 10 December 2018].

Weil ED, Levchik SV (2009). Flame Retardants for Plastics and Textiles: Practical Applications, Carl Hanser Verlag GmbH & Co. KG.

Weir RJ Jr, Fisher RS (1972). Toxicologic studies on borax and boric acid. Toxicol Appl Pharmacol. 23(3):351-64.

www.pops.int

Secretariat of the Stockholm Convention

Office address:

United Nations Environment Programme (UNEP)
International Environment House 1
11-13 Chemin des Anémones
CH-1219 Châtelaine GE
Switzerland

Postal address :

Palais des Nations
Avenue de la Paix 8-14
CH-1211 Genève 10
Switzerland

Tel: +41 22 917 82 71

Email: brs@un.org

Designed and Printed at United Nations, Geneva – 2313769 **(E)** – October 2023 – 1 – **UNEP/BRS/2023/6/iPub**