Environment Canada Environnement Canada

RISK MANAGEMENT STRATEGY

FOR

POLYBROMINATED DIPHENYL ETHERS (PBDEs)

2010

PBDE	**CAS No.***
tetrabromodiphenyl ethers (tetraBDE)	40088-47-9
pentabromodiphenyl ethers (pentaBDE)	32534-81-9
hexabromodiphenyl ethers (hexaBDE)	36483-60-0
heptabromodiphenyl ethers (heptaBDE)	68928-80-3
octabromodiphenyl ethers (octaBDE)	32536-52-0
nonabromodiphenyl ethers (nonaBDE)	63936-56-1
decabromodiphenyl ether (decaBDE)	1163-19-5

Chemicals Sectors Directorate
Environmental Stewardship Branch

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* Chemical Abstracts Service (CAS) Registry Numbers

Canada

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1. ISSUE

Ecological and human health screening assessments were conducted for polybrominated diphenyl ethers (PBDEs) under the *Canadian Environmental Protection Act, 1999* (CEPA 1999). Included in these screening assessments are seven PBDE congener groups (tetraBDE, pentaBDE, hexaBDE, heptaBDE, octaBDE, nonaBDE and decaBDE) that are contained in three commercial PBDE mixtures. A summary of the final ecological and human health screening assessment reports was published in Part I of the *Canada Gazette* on July 1, 2006 (Canada, Department of the Environment, Department of Health 2006).

The ecological screening assessment report (Environment Canada 2006) concluded that PBDEs are entering the environment in a quantity or concentration or under conditions that have or may have an immediate or long-term harmful effect on the environment or its biological diversity. The screening assessment recommended that PBDEs with four or more bromine atoms (tetraBDE, pentaBDE, hexaBDE, heptaBDE, octaBDE, nonaBDE and decaBDE congeners) be added to the List of Toxic Substances in Schedule 1 of CEPA 1999. On December 27, 2006, the order to add these PBDE congeners to the List of Toxic Substances in Schedule 1 of CEPA 1999 was published in the *Canada Gazette*, Part II (Canada. 2006).

It also concluded that tetra-, penta- and hexaBDE congeners meet the criteria for persistence and bioaccumulation, as defined by the *Persistence and Bioaccumulation Regulations* of CEPA 1999, and their presence in the environment results primarily from human activity. Therefore, tetraBDE, pentaBDE and hexaBDEs meet the conditions set out in CEPA 1999 for mandatory addition to the Virtual Elimination List.

In addition, an ecological State of Science Report on decaBDE (Environment Canada. 2010) was published (draft in March 2009, final in August 2010) which concludes that decaBDE may accumulate to levels considered to be high in organisms, and may transform into bioaccumulative and/or potentially bioaccumulative substances, including transformation into tetra-, penta- and hexaBDE congeners. The conclusions of this report were taken into account in the elaboration of the risk management measures for PBDEs proposed in this document.

The State of the Science Report for a Screening Health Assessment for PBDEs (Health Canada 2006) concluded that worst-case estimates of the exposure of Canadians to PBDEs are much lower than those that caused health effects in laboratory animals. It is anticipated that the control measures that Environment Canada is proposing to protect the environment from PBDEs will result in a reduction of human exposure to these congeners (Health Canada 2006). Health Canada is fully supportive of taking control measures to prevent exposure to

PBDEs from increasing to a level that could pose a risk to the health of Canadians.

Other jurisdictions are moving forward on further assessment and/or management actions for PBDEs, including decaBDE. Three risk assessment reports for decabromodiphenyl ether (decaBDE) were produced by the UK Environment Agency under the EU Existing Substances Regulation (ESR). These reports reviewed the main scientific literature published up to October 2006 and the EU Risk Assessment was published in the EU Official Journal in May 2008 (European Commission RA. 2008).
In September 2009, the UK Environmental Agency Science Program published an updated decaBDE Environmental Risk Evaluation environmental report[1] identifiying concerns regarding the potential of decaBDE to transform into hazardous degradation products. DecaDBE will now go through the REACH (Registration, Evaluation, Authorisation and Restriction of Chemicals) framework of the EU.

In the United States, an Action Plan for PBDEs was published by the Environmental Protection Agency (U.S. EPA) in December 2009 which includes support for the phase-out of DecaBDE following commitments from the principal manufacturers and importers to voluntarily phase-out manufacturing and import of the substance in the US by December 31, 2013 (see Section 5 for details). In consideration of the conclusions of Canadian assessments of PBDEs (Section 3) and international actions (Section 5), stringent risk management measures for all forms of PBDEs assessed under CEPA are proposed herein.

2. BACKGROUND

2.1 Substance Information

Polybrominated diphenyl ethers (PBDEs) are a class of substances that have been used as flame retardants in a wide variety of products. These substances contain an identical base structure, but differ in the number of attached bromine atoms (ranging from 1 to 10). The following seven PBDE congener groups, present on the Canadian Domestic Substances List, were assessed by Environment Canada and Health Canada:

[1] The UK Environmental Agency risk assessment report, is available at the following address: http://publications.environment-agency.gov.uk/pdf/SCHO0909BQYZ-e-e.pdf

PBDE	***CAS No.****	***Molecular Formula***
tetrabromodiphenyl ethers (tetraBDE)	40088-47-9	$C_{12}H_6Br_4O$
pentabromodiphenyl ethers (pentaBDE)	32534-81-9	$C_{12}H_5Br_5O$
hexabromodiphenyl ethers (hexaBDE)	36483-60-0	$C_{12}H_4Br_6O$
heptabromodiphenyl ethers (heptaBDE)	68928-80-3	$C_{12}H_3Br_7O$
octabromodiphenyl ethers (octaBDE)	32536-52-0	$C_{12}H_2Br_8O$
nonabromodiphenyl ethers (nonaBDE)	63936-56-1	$C_{12}HBr_9O$
decabromodiphenyl ether (decaBDE)	1163-19-5	$C_{12}Br_{10}O$

* Chemical Abstracts Service (CAS) Registry Numbers

All seven PBDE groups assessed are highly persistent and many PBDE congeners have been detected in the Arctic, thus indicating that they are subject to long-range environmental transport (Environment Canada 2006). Each satisfies the requirements for persistence as defined in the *Persistence and Bioaccumulation Regulations* under CEPA 1999 (Canada. 2000).

In addition, based on the final ecological screening assessment report, tetra-, penta- and hexaBDE congeners are highly bioaccumulative and satisfy the criteria for bioaccumulation under these same Regulations. As these PBDEs also result primarily from human activity, they meet the conditions set out in subsection 77(3) of CEPA 1999 for mandatory addition to the Virtual Elimination List.

The results of the final State of the Science report on decabromodiphenyl ether (decaBDE) were published in the *Canada Gazette*, Part I on August 28,2010. The purpose of the report is to provide an updated analysis of the bioaccumulation and environmental transformation of decabromodiphenyl ether, to be considered in the context of the information and analyses already published in the final screening assessment on PBDEs.

The State of Science Report found no measured or experimental evidence supporting that decaBDE meets the bioaccumulation criteria as defined under the *Persistence and Bioaccumulation Regulations* under CEPA 1999. However, several studies indicate that decaBDE is available for uptake in organisms and may accumulate to high and potentially problematic levels in certain species. Although uncertainties remain, it is reasonable to conclude that decaBDE may contribute to the formation of bioaccumulative and/or potentially bioaccumulative transformation products such as lower-brominated PBDEs, including tetra-, penta- and hexaBDEs, in organisms and in the environment.

PBDEs are considered to present a negligible risk with respect to atmospheric processes such as global warming, stratospheric ozone depletion and ground-level ozone formation. This is due to the tendency of PBDEs entering the environment to bind to the organic fraction of particulate matter, notably in sediment and soil, with only small amounts partitioning into water and air.

2.2 Chronology of the PBDE File

Numerous actions have been completed by the Government of Canada concerning PBDEs; key milestones to date are summarized below:

Milestone	**Date**
Summary of the final ecological and human health screening assessment reports published in the *Canada Gazette*, Part I (CGI) (Canada, Department of the Environment, Department of Health. 2006)	July 1, 2006
Proposed Risk Management Strategy posted online for public comment	Sept. 20, 2006
Proposed *Polybrominated Diphenyl Ethers Regulations* published in the *Canada Gazette,* Part I	Dec. 16, 2006
60-day electronic consultation on proposed PBDE regulations	Dec. 16, 2006-Feb. 14, 2007
Final Order Adding to the List of Toxic Substances published in the *Canada Gazette*, Part II (CGII) (Canada. 2006)	Dec. 27, 2006
Final *Polybrominated Diphenyl Ethers Regulations* (PBDE Regulations) made and in force (Canada. 2008)	June 19, 2008 (published in CGII July 9, 2008)
Draft State of Science Report on the Bioaccumulation and Transformation of Decabromodiphenyl Ether	March 28, 2009
Revised Risk Management Strategy published for public comment.	March 28, 2009
Final State of Science Report on the Bioaccumulation and Transformation of Decabromodiphenyl Ether	August 28, 2010

2.3 Production, Import, Export and Uses of PBDEs

PBDEs are sold in three commercial mixtures—PentaBDE, OctaBDE and DecaBDE—each containing two or more of the seven PBDE congener groups. Although the commercial mixtures vary in composition, each PBDE congener

group is typically present within a certain range. Typical compositions of the commercial mixtures are shown in Figure 1.

Figure 1 – Typical compositions of the PBDE commercial mixtures[2]

Commercial Mixtures	PBDE Congener Groups						
	tetraBDE	pentaBDE	hexaBDE	heptaBDE	octaBDE	nonaBDE	decaBDE
PentaBDE	24-38%	50-62%	4-12%	Trace	-	-	-
OctaBDE	-	0.5%	12%	45%	33%	10%	0.7%
DecaBDE	-	-	-	-	Trace	0.3-3%	97-98%

PBDE congeners that meet the conditions set out in CEPA 1999 for Virtual Elimination.

PBDEs have never been manufactured in Canada. Due to voluntary phase-out by industry, production in the United States of the PentaBDE and OctaBDE commercial mixtures ceased at the end of 2004, followed by phase-out on an international basis.

The DecaBDE commercial mixture is manufactured outside of Canada. DecaBDE is imported and enters Canada:

- as chemical formulations from foreign producers;
- in resins, polymers or substrates containing DecaBDE;
- in semi-finished articles, materials or components containing DecaBDE; or
- in finished products containing DecaBDE.

Ongoing assessment and management of PBDEs in other jurisdictions in concert with the announcement by the three largest manufacturers of DecaBDE of their intention to voluntarily phase-out production and import of DecaBDE for the US market by 2013 is expected to significantly decrease the use of this commercial mixture in Canada in the next few years. These three manufacturers have also proposed to phase out the import of DecaBDE into Canada. This will further contribute to the decreased use of DecaBDE in Canada.

In general, plastics are the primary end use for flame retardants owing to the inherent flammability of many polymers. PBDEs have seen widespread use in electrical and electronic goods, transportation, textiles and construction/industrial products.

[2] For the purposes of this document, PBDE commercial mixtures are capitalized to distinguish from the congeners they contain (i.e. “PentaBDE” vs. “pentaBDE”).

There are substantial differences in the use patterns of the three commercial mixtures.

PentaBDE Commercial Mixture

The PentaBDE commercial mixture was primarily used in polyurethane resins, particularly foams. The downstream industries that used such products were primarily the users of flame-retardant polyurethane (PUR) foams, e.g. furniture and bedding manufacturers, manufacturers of moulded and slab foams for automotive parts, manufacturers of carpets and rugs with polyurethane underlay, and manufacturers of building construction foam.

PentaBDE is no longer manufactured worldwide; however there is a sizeable end of life issue with products containing the substance still in use and/or in landfill (see Section 8.6).

OctaBDE Commercial Mixture

The OctaBDE commercial mixture was primarily used in acrylonitrile butadiene styrene (ABS) resins. The downstream industries that used OctaBDE-containing ABS were the manufacturers of electrical and electronic products, since such resins were used for computer housings, appliances, automotive parts and communication equipment.

Similar to PentaBDE, the primary concern with the OctaBDE mixture is for management of products at end of life (see Section 8.6).

DecaBDE Commercial Mixture

The DecaBDE commercial mixture is used primarily in polystyrene (PS), particularly high impact polystyrene (HIPS) and to a lesser extent in a number of other resins. These DecaBDE flame retardant resins are predominantly used in electrical and electronic equipment (EEE) products, transportation products, textile related products (e.g. upholstery and draperies) and construction/industrial products.

Reports indicate that prior to 2008, 80–90% of DecaBDE (Cheminfo 2008) was used in electrical and electronic equipment (EEE) products, with textile applications accounting for most of the remaining 10–20%. Since 2008, the European Union Reduction in the Use of Hazardous Substances (RoHS) Directive, has been restricting DecaBDE use domestically in certain EEE products. As a result, the use profile has changed so that transportation and textiles now represent a much larger percentage of DecaBDE use in products.

While information gathered in 2001 through an Environment Canada use pattern survey revealed that 16 Canadian manufacturers reported importing approximately 1300 tonnes of PBDEs in 2000 (Environment Canada 2003), the use of PBDEs in Canada has since declined significantly. The PentaBDE and OctaBDE commercial mixtures are no longer available worldwide and discussions with industry indicate that the amount of DecaBDE imported into Canada has generally decreased over the last few years. Gross estimates for 2009 indicate that up to 3000 tonnes of DecaBDE enter the Canadian market from all sources (substance & within manufactured/imported products)[3], work continues to refine this estimate. While the use of the PentaBDE and OctaBDE commercial mixtures have been phased out, they may be present in older materials and manufactured products (i.e. manufactured prior to 2006), either currently still in use or imported into Canada.

Not all imported PBDEs remain within Canada, as some are exported from Canada in finished products, most of which are destined for the United States.

3. WHY WE NEED ACTION

According to the ecological assessment report (Environment Canada 2006), PBDEs are entering the environment in a quantity or concentration or under conditions that have or may have an immediate or long-term harmful effect on the environment or its biological diversity. PBDEs have been detected in a variety of species worldwide and evidence from many studies indicates that levels of certain PBDEs in biota in North America (including the Canadian Arctic) are increasing steadily and substantially over time. The assessment report indicates that the greatest potential risks from PBDEs in the Canadian environment are the secondary poisoning of wildlife from the consumption of prey containing elevated concentrations of PBDEs and effects on benthic organisms that may result from elevated concentrations of certain PBDEs in sediments. The State of Science Report (Environment Canada 2010) found that decaBDE is available for uptake and has the potential to accumulate in biota to high levels and can contribute, in some cases, to a significant proportion of the PBDE burden in biological tissues.

Given the conclusions of both the final ecological screening assessment and the State of the Science report on decaBDE, PBDEs are and will be managed under the provisions of CEPA 1999 with the objectives of preventing their manufacture, import and export in Canada. Actions will also be undertaken to minimize their release into the environment from other sources entering into Canada, such as PBDEs in imported products.

[3] Estimate based on approximation of percentage of consumption of products containing DecaBDE in Canada versus worldwide and using estimates of the amount of DecaBDE consumed worldwide.

For tetra-, penta-, and hexaBDE congeners, the ultimate environmental objective is virtual elimination (VE) as they result primarily from human activity, and meet the criteria for bioaccumulation, persistence and toxicity as defined under CEPA 1999. Currently the use, sale, offer for sale and import of these substances is prohibited in Canada.

With respect to decaBDE, the State of Science Report (Environment Canada. 2010) concludes that decaBDE may accumulate to levels considered to be high in organisms, and may transform into bioaccumulative and/or potentially bioaccumulative substances, including transformation into tetra-, penta- and hexaBDE congeners.

The intent, therefore is to align all substance based controls for all PBDEs assessed under CEPA, such that restrictions on the use, sale, offer for sale and import would apply to all congeners and not just those slated for virtual elimination.

The intent is also to pursue new product based restrictions on all PBDEs, including decaBDE (see Section 8). This approach will require consultations to gather information on current use trends in a wide number of sectors.

Additionally, PentaBDE and OctaBDE (c-PentaBDE and c-OctaBDE) have recently been added to the Stockholm Convention on Persistent Organic Pollutants (POPs) and the United Nations Economic Commission for Europe (UNECE) Long-Range Transboundary Air Pollution (LRTAP) POPs Protocol, of which Canada is a signatory.

4. PRESENCE IN THE CANADIAN ENVIRONMENT AND EXPOSURE SOURCES

There are no known natural sources of PBDEs. PBDEs are potentially released to the environment throughout their lifecycle, from the chemicals themselves and from products containing them. PBDEs may enter the environment through treated or untreated municipal or industrial wastewater discharges to surface water and also through leachate from landfills and municipal incineration when products and materials containing these substances are sent for final disposal. PBDEs may also be released directly to air, land and surface water when products containing PBDEs are manufactured and during their use. These exposure sources are discussed in this section.

Products that were treated with PentaBDE or OctaBDE prior to phase-out that remain in use will continue to be a source of release to the environment, primarily via disposal. Potential releases of the DecaBDE commercial mixture from

plastics are mainly associated with product disposal as well. Potential releases of the DecaBDE commercial mixture associated with textile applications appear to be spread relatively evenly throughout the life cycle, with most releases being associated with textile processing/finishing and releases during the product service life.

4.1 Industrial and Manufacturing Processes

PBDEs are not manufactured in Canada. Only the DecaBDE commercial mixture remains in use, while the other PBDEs (Penta- and OctaBDE mixtures) have been phased out internationally. Since the three largest manufacturers of DecaBDE recently announced their intention to phase-out production of DecaBDE in the US, import sales of this commercial mixture have declined significantly in Canada, and further significant reductions are forecasted. This will reduce the risk of DecaBDE emissions at Canadian product manufacturing facilities. In addition, the three manufacturers proposal to phase out the import of DecaBDE to Canada will further reduce the risk of DecaBDE emissions.

DecaBDE has been primarily used in industrial and manufacturing processes to treat plastics and textiles in order to impart flame retardancy to products. While North American manufacture of DecaBDE is declining significantly as noted above, it is still being manufactured in China and the Middle East.

The release of PBDEs from these sources can occur during the handling of PBDEs prior to formulation, during the formulation and processing of PBDEs into resins and during the conversion of these resins into products. Residues on packaging of the industrial chemical are another important source of release for DecaBDE[4]. Releases of PBDEs, including DecaBDE, from industrial or manufacturing processes will primarily be to wastewater, to air through vaporization and to land from spills and waste disposal. The majority of air releases from manufacturing facilities would rapidly partition to soil and sediments (from 75 to > 99%) and remain near their point of release (ToxEcology Environmental Consulting 2003).

4.2 Product Use

The day-to-day use of products containing PBDE flame retardants has the potential to release PBDEs to the environment. Emission to air has been identified as a potential source of release due to the vaporization of PBDEs from products. Air releases may be one pathway for PBDE presence in dust. Particle emissions may also result from aging and wear of products (e.g. foam particles from furniture, plastic housings of electronic equipment, plastics in vehicle interiors).

[4] http://www.vecap.info/uploads/NewsPublications/documents/VECAP_report_22%2001.pdf

PBDEs are released to wastewater, some of which makes its way to the municipal treatment facility through the disposal of wash water containing PBDEs present in dust. While potential releases to wastewater have also been identified from the washing of textiles, PBDEs are generally used in textiles such as upholstery fabrics, carpets, curtains and tent materials, which are not subject to frequent washing (ToxEcology Environmental Consulting 2003).

4.3 Product Disposal

The term "products" as used in this report refers to articles to which PBDE commercial mixtures have been added. Products may include, for example, furniture, carpet backing, textiles, televisions, electronic equipment, computer housings, and automotive components.

The majority of PBDEs used in products remain in the product matrices at the time of disposal. At present, in Canada, the majority of solid articles containing PBDEs are disposed of in landfills[5] (ToxEcology Environmental Consulting 2003).

The release of PBDEs occurs when products containing PBDEs are disposed of in landfill sites at the end of their operational life or, in the case of some products, are sent to recycling facilities for processing. Releases may occur at various points during disposal and recycling operations including handling, transport and product breakup at collection sites. While municipal incineration of solid waste is a potential source of PBDE emissions, incineration represents less than 5% of solid waste disposal in Canada (ToxEcology Environmental Consulting 2003).

Landfilling may result in releases of PBDEs to soil, surface water and potentially to groundwater. Based on their properties, it is assumed that PBDEs will partition to soil and sediments and remain close to the point of release. Releases from landfills are dependent on the concentration of these substances remaining in the products at their end of life, landfilling practices and the existence of leachate collection systems.

It should be noted that potentially PBDE-contaminated leachate collected from landfills is normally taken to municipal treatment facilities. Since PBDEs are not removed during treatment at these facilities, the PBDEs either pass directly

[5] Though the majority of electronic equipment containing PBDEs is sent to landfills, an increasing amount of end of life (EOL) electronics is subject to extended producer responsibility (EPR) programs. These programs are set up by provincial or regional governments in concert with industry, most of which are mandatory. These programs support waste reduction, reuse and recycling, and are designed to encourage education in use and pollution prevention related to toxic substances. Although PBDEs are not individually identified in the EPR programs, these programs target products that may contain PBDEs.

through the facility and into the downstream aquatic environment or else are contained in bio-solid sludge that is either applied to land or returned to the landfill that originally generated the leachate (Cheminfo 2008).

Under the Stockholm Convention, there was recognition on the complexity around the types and quantities of articles recycled as well as the extent of recycling options for environmentally sound disposal of articles containing PentaBDE and OctaBDE. As such a work program was established to obtain more information on these issues. Canada will participate in this work program and will use the results to further its risk management actions in this area.

4.4 Long-Range Transport

PBDEs have been detected in remote sites around the world, including the Canadian Arctic where they are present at elevated levels (e.g. in air, lakes and in the tissues of some living organisms), suggesting that the PBDEs undergo long-range transport (Environment Canada 2006). This long-range transport of PBDEs through the atmosphere or through the ocean currents is a potential source of PBDE loadings to the Canadian environment. Manufacturing of PBDEs, manufacturing processes using PBDEs, as well as use and disposal of formulations and products outside of Canada are expected to contribute to the presence of PBDEs in Canada.

4.5 Transformation of decaBDE

DecaBDE likely contributes to the formation of bioaccumulative and/or potentially bioaccumulative transformation products such as lower brominated BDEs in organisms and in the environment. Numerous laboratory studies provide evidence that decaBDE may break down in the environment, particularly as a result of photodegradation and biodegradation. Studies of photodegradation of decaBDE sorbed to solids in aqueous and dry systems have demonstrated transformation of decaBDE to tri- to nonaBDEs. Biodegradation studies have also shown the potential breakdown of decaBDE mainly to nona-, octa- and heptaBDEs (Environment Canada. 2010).

5. OVERVIEW OF EXISTING INTERNATIONAL INITIATIVES ON PBDEs

There are numerous regulatory initiatives concerning PBDEs that have been enacted in various jurisdictions around the world, the majority of which are targeting PBDEs contained in electronic and electrical equipment (EEE). Increasingly, however, jurisdictions are targeting restrictions on the content of PBDEs in additional product types (in addition to EEE).

5.1 European Initiatives

5.1.1 European Commission

Under the European Union (EU) RoHS (Restriction of the Use of Certain Hazardous Substances in Electrical and Electronic Equipment) Directive 2002/95/EC (European Parliament and Council of the European Union 2003a), six substances (or class of substances), including PentaBDE and OctaBDE commercial mixtures, have been restricted within specified electronic and electrical equipment (EEE) product types since July 1, 2006. As of July 1, 2008, use of DecaBDE mixture has also been restricted, which means that all 7 PBDE congener groups ((tetraBDE, pentaBDE, hexaBDE, heptaBDE, octaBDE, nonaBDE and decaBDE congeners) are covered under the Directive as of that date. For PBDEs, the restriction is for content within products greater than 0.1% by weight (European Parliament and Council of the European Union 2005) at the homogeneous[6] level of a product. A draft proposal to update the EU RoHS Directive (Commission of the European Communities 2008) was published in late 2008, aimed at increasing the number of product groups affected by the Directive, in addition to changes in labeling requirements and the streamlining of some requirements. There are currently no exemptions applying to PBDEs in the Directive.

An Environmental Risk Assessment Report on decaBDE from the EU[7], published in September 2009, confirms that DecaBDE has the potential to degrade into a number of dangerous and polluting chemicals, including some which have been added to the Stockholm Convention on persistent organic pollutants. This report is being used, in the EU, as a basis to assess whether controls on products other than EEE products should be enacted for the EU. Any controls on DecaBDE for products other than EEE are to be carried out under the EU REACH (Registration, Evaluation, Authorisation and Restriction of Chemicals) Regulation.

The European Union's Waste Electrical and Electronic Equipment (WEEE) Directive 2002/96/EC (European Parliament and Council of the European Union 2003b) has been in force since January 2003 (initially adopted by a number of EU countries in August 2005). The WEEE directive aims to prevent the generation of electrical and electronic waste and to promote reuse, recycling and other forms of recovery in order to reduce the quantity of such waste being disposed of through landfilling or incineration. The WEEE Directive requires EEE industry producers to take back and recycle their products, with targets for the amount of recycling achieved in addition to various other requirements. A requirement of WEEE is that plastics containing brominated flame retardants

[6] The definition of a homogeneous material can be found in the Frequently Asked Questions on EU RoHS and EU WEEE (European Commission 2006) and in the proposal to update the EU RoHS Directive (Commission of the European Communities 2008).
[7] http://publications.environment-agency.gov.uk/pdf/SCHO0909BQYZ-e-e.pdf

(including PBDEs) be removed from the EEE waste and necessary measures be taken to ensure the resulting waste is disposed of without endangering human health or the environment. The EU WEEE Directive is linked to the EU RoHS Directive in that the product types affected by EU RoHS are contained in Annex 1A[8] of the EU WEEE Directive.

As a consequence of requirements of both the RoHS Directive and the WEEE Directives, methods have emerged in Europe for the treatment of plastics to remove BFRs (including PBDEs). These emerging technologies enable the use of recycled plastics into new EEE products, while still meeting the PBDE content restriction of the RoHS.[9]

The European Union Directive 2003/11/EC (European Parliament and Council of the European Union 2003c) has been in force since August 15, 2004. The Directive prohibits the use of PentaBDE and OctaBDE commercial mixtures in all manufactured or imported products at concentrations higher than 0.1% by mass.

5.1.2 Other European Countries

Some other European countries that are not part of the European Union, including Switzerland, Iceland, Liechtenstein and Turkey have also essentially adopted the EU RoHS regulations, with some country-specific variations.

Norway has enacted regulations restricting the use of PentaBDE and OctaBDE in all manufactured products effective August 15, 2004 and July 1, 2004, respectively. Norway has also enacted regulations restricting the use of DecaBDE in all manufactured products, with the exception of transportation applications (the restriction applies to concentrations > 0.1% by weight, same as in EU RoHS). The regulations have been in force since April 1, 2008. In addition, in Norway, products containing more than 0.25% PentaBDE, OctaBDE or DecaBDE commercial mixtures are classified as hazardous waste when they are discarded.

5.2 Initiatives in the United States

In June 2006, the United States Environmental Protection Agency (U.S. EPA) issued a Significant New Use Rule (SNUR)[10] that requires notification to the U.S. EPA 90 days prior to US manufacture or import, for any use, of the commercial PentaBDE and OctaBDE mixtures for prior evaluation.

Trends in releases of decaBDE are also being followed by the United States through the Toxics Release Inventory. In June 2008 the U.S. EPA released the

[8] Annex 1A of the EU WEEE Directive (European Parliament and Council of the European Union 2003b) can be found on page 33 of that document.
[9] For more information, see **http://www.axionrecycling.com**.
[10] For more information, see **http://www.epa.gov/opptintr/newchems/pubs/cnosnurs.htm**.

final Integrated Risk Assessment Information System (IRIS)[11] assessment of decaBDE.

The EPA's Design for the Environment (DfE)[12] Program, which began in the early 1990's, works to provide information on substituting safer chemicals and provides for assessment of alternatives, including alternatives to PBDEs.

On December 30, 2009 the three largest manufacturers of the decaBDE substance, in concert with the Environmental Protection Agency in the United States (US EPA), announced their intention to phase out the production of the substance in the United States[13] as well as the phase out of the import of the substance to the US. Timelines established are for a phase out of the availability of the decaBDE substance for use within all but transportation and military products by December 31, 2012 and a complete phase out of decaBDE for all uses by December 31, 2013 (subject to a 6 month additional delay to deplete potential stock of the substance).

A **US EPA Action Plan** for PBDEs, published in December 2009, includes the following measures:

- Support for the phase-out of DecaBDE following commitments from the principal
  manufacturers and importers to phase-out manufacturing and import of the substance in the US by December 31, 2013.
- Initiate TSCA (Toxic Substances Control Act) §5(b)(4) Concern List rulemaking on PBDEs. Proposed rule to be in place by late Fall 2010.
- Initiate action to include articles in current Penta/OctaBDE SNUR, which requires
  new chemical notices for new uses or imports. Proposed SNUR is to be in place by August 2010.
- Initiate rulemaking to simultaneously propose a SNUR and the previously announced TSCA §4 test rule for DecaBDE. The significant new use would be manufacture, (including import) of DecaBDE or articles to which DecaBDE has been added. The test rule would require laboratory studies to determine the effects that decaBDE has on human health and the environment. Timing of the proposed SNUR and test rule is expected to coincide with completion of phase out by manufacturers in 2013.

[11] For more information, see **http://cfpub.epa.gov/ncea/iris/index.cfm**.
[12] For more information, see **http://www.epa.gov/dfe/**.
[13] Information on the DecaBDE Phase Out initiative and commitment letters from the manufacturers available at:
http://www.epa.gov/oppt/existingchemicals/pubs/actionplans/deccadbe.html

5.2.1 Initiatives by Individual U.S. States

Laws have been enacted and legislation introduced relating to PBDEs in many U.S. States (The Toxics Steering Group and Polybrominated Diphenyl Ethers Subcommittee 2008), including California, Hawaii, Illinois, Maryland, Maine, Michigan, Minnesota, New York, Oregon, Rhode Island, Washington and Vermont. These legislative initiatives initially addressed the PentaBDE and OctaBDE commercial mixtures. However, several states are now proposing restricted uses of DecaBDE as well. Many of the legislative initiatives concerning DecaBDE are still under discussion by the States in question. However, four States, Washington[14], Maine, Vermont[15] and Oregon[16], have signed into law legislation prohibiting the use of DecaBDE in certain consumer products:

- The state of Washington has restricted the manufacture, sale, and use of DecaBDE in mattresses as of January 2008. That restriction has now been extended to televisions, computers and residential upholstered furniture, effective January 2011.

- The state of Maine has restricted the use of DecaBDE in mattresses and upholstered furniture as of January 1, 2008. As of January 1, 2010 the restrictions were extended to include televisions and other plastic-cased electronics.

- The state of Vermont recently passed a law which prohibits the manufacture, sale or distribution of a mattress, mattress pad or upholstered furniture intended for residential occupancy containing DecaBDE, effective July 1, 2010. The law also prohibits the manufacture, sale or distribution of a television or computer with a plastic housing containing DecaBDE, effective July 1, 2011.

- The State of Oregon passed a law which prohibits the introduction into commerce of any product, excluding transport applications, which contains more than 0.1% by mass of DecaBDE, effective January 1, 2011.

[14] Further information is available on the Washington Department of Ecology's PBDE website: **http://www.ecy.wa.gov/programs/swfa/pbt/pbde.html**
[15] Further information on the Vermont health care bill is available at: **http://www.leg.state.vt.us/docs/2010/bills/Senate/H-444.pdf**
[16] Further information on the Oregon bill is available at the Oregon Environmental Council website: **http://www.oeconline.org/our-work/smart-policy**

5.3 Asian Initiatives

Japan has a law concerning the reporting of releases of specific chemical substances and promoting improvements in their management. Under this law, yearly reports are required on the volumes of the DecaBDE commercial mixture imported and used and the quantities released to the environment.

China's Ministry of Information Industries issued the Management Methods for the Prevention and Control of Pollution Caused by Electronic Information Products (sometimes referred to as CRoHS). The ministry is taking a phased approach to managing the same six substances restricted under EU RoHS, including PBDEs.

The first phase of CRoHS, in force since March 1, 2007, requires labeling and disclosure of the content of the substances within EEE products, but imposes no restrictions.

The second phase of CRoHS includes the creation of a Key Catalogue detailing the list of products types which will be restricted, together with provisions specific to those product types. On October 9, 2009 a draft of the first installment of the China RoHS Key Catalogue, which contains restrictions on all types of phones (including mobile phones) and printers, was published for consultation. The restrictions are slated to come into force ten months after adoption of the legislation. The restricted substances are the same as for EU RoHS, excluding DecaBDE, as are the maximum permitted concentration levels at homogeneous material level.

Korea implemented a law which covers end-of-life and EU-RoHS-type restrictions on electronic products and vehicles. Exemptions, limit values and restricted substances are the same as the EU RoHS Directive. As of July 1, 2008, a restriction similar to EU RoHS, including for PBDEs, came into force for a subset of the product types included in EU RoHS.

5.4 International Agreements

Canada played an active role in the process of adding PentaBDE (c-PentaBDE) and OctaBDE (c-OctaBDE) to two international agreements: the Stockholm Convention on Persistence Organic Pollutants (POPs) and the Persistent Organic Pollutant (POPs) Protocol of the United Nations Convention on Long-range Transboundary Air Pollution (LRTAP). These chemicals have been added to these conventions as certain PBDEs contained in them have the ability to undergo long-range transport, are persistent and bioaccumulative and are deemed to have sufficient indications that they are likely to cause adverse effects as a result of their long-range transport.

5.4.1 Stockholm Convention on Persistent Organic Pollutants (POPs)

The Stockholm Convention entered into force in May 2004 and is an international legally binding agreement that has been ratified by 128 countries, including Canada. Under this convention, Parties are bound to take action to prohibit the manufacture and import of the chemicals listed on Annex A and B of the Convention.

In May 2009, the Fourth Conference of the Parties (COP4) decided to list PentaBDE and OctaBDE congeners (tetra-, penta-, hexa- and heptaBDE) to Part 1 of Annex A of the Convention, with specific exemptions for recycling articles, until 2030. COP4 also decided to establish work programs to further understand issues related to recycling and waste associated with the PentaBDE and OctaBDE listing. Listing in Annex A obliges the Parties, including Canada, to eliminate the production, use, export and import of the chemical.

5.4.2 United Nations Economic Commission for Europe (UNECE) Long-Range Transboundary Air Pollution (LRTAP) Convention's Protocol on Persistent Organic Pollutants (POPs) ("LRTAP Convention")

The LRTAP Convention entered into force in 1953 and is an international legally binding agreement that has been ratified by 51 countries, including Canada. The Convention requires all Parties to endeavor to limit and, as far as possible, gradually reduce and prevent air pollution including long-range transboundary air pollution.

Parties to the LRTAP Convention have concluded that PentaBDE and OctaBDE are persistent organic pollutants. An assessment and management review of PentaBDE and OctaBDE has been completed by the UNECE's LRTAP. In December 2009 at the 27th session of the Executive Body, the components of the PentaBDE and OctaBDE commercial mixture (i.e. tetraBDE, pentaBDE, hexaBDE and heptaBDE) were added to Annex I of the POPs Protocol to eliminate their production and use.

5.5 Environmental Stewardship Programs

In May 2004, the Voluntary Emissions Control Action Programme (VECAP)[17] was initiated by the British Plastics Federation and the Bromine Science and Environmental Forum. Under this program, a voluntary code of practice was developed to manage, monitor and minimize industrial emissions of brominated flame retardants into the environment through partnership with small and medium-sized enterprises. The initial focus of the program was on textile and plastics industries in Europe, but implementation has spread to the United States and Japan.

[17] Further information on VECAP is available at **http://vecap.org/**.

A program called the Electronic Product Environmental Assessment Tool (EPEAT)[18] was created by a multi-stakeholder group in the United States. EPEAT is a procurement tool used to identify desktop computers, notebooks and monitors that satisfy established environmental criteria, including conformance to EU RoHS.

Environment Canada's Environmental Choice Program has recently concluded a partnership with the US-based EPEAT program by which electronic manufacturers have the option to apply for the third-party-verified EcoLogo certification for products that qualify the silver and gold EPEAT registration levels. To qualify for the EPEAT registration and EcoLogo certification of personal computer products (namely desktop personal computers, notebook personal computers and personal computer monitors) manufacturer's products must comply with a number of performance criteria including the provisions of the European RoHS Directive 2002/95/EC for the restriction on certain hazardous substances in electronic equipment (which include PBDE).[19]

6. CONSIDERATIONS

PBDEs are used in products to slow the ignition and spread of fire. In working towards the risk management objectives (see section 7.2), there is a need to weigh one potential risk against another. Flame retardancy is important to protect human safety and avoid social and economic losses due to fire. In addition, many toxic substances are released during fires; hence, flame retardancy can yield net environmental benefits. Cost-effective substitutes or alternatives must be available to meet the relevant fire safety standards.

6.1 Alternative Chemicals

Chemical alternatives to PBDEs are available for the vast majority of industrial and manufacturing applications, and these vary by application. However, several issues need to be addressed as some potential alternatives are:

- currently under scrutiny themselves;
- new proprietary chemicals for which data on environmental and health effects are very limited;
- more costly; and
- less effective; hence much higher levels are required and products may be less likely to meet flammability standards.

[18] Further information on EPEAT is available at **http://www.epeat.net/**.
[19] Further information on the EcoLogo program is available at **http://www.ecologo.org/en/**.

6.2 Alternative Techniques

The need for PBDEs can be reduced through the use of alternative techniques such as:

- the use of materials that are less prone to fire hazard in electronics equipment (such as aluminum or “super-plastics” with very high oxygen requirements for combustion);
- the use of barrier fabrics, wrappings or coatings for foams to replace chemical flame retardants;
- the use of inherently flame retardant fibres.

Some of these alternative techniques present challenges, such as the increased weight of final products.

Some of these alternative techniques are promoted and encouraged by Design for the Environment (DfE) programs (see section 5.2). DfE programs also promote innovation, informed substitution, alternatives analysis, and green chemistry.

7. PROPOSED OBJECTIVES

7.1 Environmental Objective

The environmental objective for all seven PBDE congener groups is to reduce the concentrations of PBDEs in the Canadian environment to the lowest level possible.

7.2 Risk Management Objectives

The proposed risk management objective for all PBDEs assessed under CEPA (tetra-decaBDEs) is intended to prevent the introduction of their manufacture in Canada, their import into Canada and to minimize their releases into the environment from all sources in Canada. This includes restrictions on the importation of the PBDE substances and products manufactured or imported into Canada that contain PBDEs.

8. RISK MANAGEMENT INSTRUMENTS/TOOLS, AND COMPLEMENTARY MEASURES

Given the conclusions of both the final ecological screening assessment on PBDEs and the State of Science report on decaBDE, as outlined in section 1 of this report, the Risk Management Strategy for PBDEs uses a multi-instrument

approach to minimize releases of PBDEs from all sources to the environment. The approach considers the need for substance and product based controls in combination with the development of environmental quality guidelines, international co-operation and ongoing monitoring as described in the following sections.

8.1 PBDEs Substance Based Controls

The *Polybrominated Diphenyl Ethers Regulations* (PBDE Regulations) were made under CEPA 1999 and came into force on June 19, 2008. The regulations prohibit the manufacture of PBDEs (i.e. tetra-, penta-, hexa-, hepta-, octa-, nona-, and decaBDE congeners) in Canada. The regulations also prohibit the manufacture, use, sale, offer for sale and import of mixtures, polymers and resins containing those PBDEs that meet the criteria for virtual elimination (tetra-, penta- and hexaBDE congeners) under CEPA 1999.

As the PentaBDE and OctaBDE commercial mixtures contain those PBDEs that meet the criteria for virtual elimination, their sale, import and use is prohibited in Canada.

As a result of the manufacturing prohibition in the PBDE Regulations, the manufacture of all of the PBDE commercial mixtures, including DecaBDE, is also prohibited in Canada.

The intention is now to align substance based controls for all PBDEs assessed under CEPA. As such, prohibitions would apply to the use, sale, offer for sale, import and export of all 7 congeners groups (tetraBDE, pentaBDE, hexaBDE, heptaBDE, octaBDE, nonaBDE and decaBDE) and any resin or polymer containing these substances.

Additional details on these regulatory controls will be made available in a consultation document on proposed risk management controls for PBDEs.

8.2 Regulatory controls to restrict PBDEs in manufactured and imported products containing tetra-, penta-, hexa-, hepta-, octa-, nona- and decaBDE congeners ("PBDE product regulatory controls")

PBDE product regulatory controls will be made under CEPA 1999.

The intention is to pursue regulatory controls which would apply to all new products and include all 7 PBDE congener groups as listed above. They would aim to prohibit the manufacture, use, sale, offer for sale, import and export of all new products containing these substances at a concentration of greater than 0.1% by weight.

Controls affecting the PentaBDE and OctaBDE commercial mixtures are preventive in nature as these commercial mixtures have been phased out internationally since 2005-2006. The controls will aim to prevent any possible re-introduction of products containing these substances into Canada.

Controls being proposed on products containing DecaBDE are broader in scope than the controls proposed in the Risk Management Strategy for PBDEs published in March 2009, which included controls for DecaBDE content in new electronic and electrical equipment.

Information is needed to effectively assess the number of products that would be impacted by this approach and the size of the regulated community. Consultations will be undertaken as a means of collecting this information. Studies and other means of information gathering will also be used.

Additional details on these regulatory controls will be made available in a consultation document on proposed risk management controls for PBDEs.

8.3 Proposed Performance Agreement for DecaBDE used at Canadian Manufacturing Facilities

The Risk Management Strategy for PBDEs published in March 2009 called for a Performance Agreement (PA) to be developed with industry on a voluntary basis to monitor and minimize the release of the Decabromodiphenyl Ether (DecaBDE) commercial mixture (containing nona- and decaBDE congeners) from Canadian plastic and textile manufacturing operations where DecaBDE is used or handled. Parties to the Agreement were to adopt a code of practice that would have set numerical performance objectives for reducing releases of DecaBDE to the environment. The three largest manufacturers of DecaBDE participated in the preparation of the draft PA.

The announcement by the three large manufacturers of DecaBDE of their intention to phase out the production of DecaBDE in the US has significantly reduced the importation of the substance into Canada, and further dramatic reductions are forecasted for 2010. The proposal by the manufacturers to phase out the import of DecaBDE to Canada will further accelerate the reductions. In addition, the Government of Canada is now proposing stringent regulatory action for all sectors, including those covered by the Performance Agreement (plastics and textiles). These initiatives surpass the objective of the proposed PA[20]. Therefore it is no longer deemed an effective tool to manage the use of DecaBDE at manufacturing facilities in Canada and will not be finalized for implementation.

[20] For an archive of this proposed Performance Agreement, please refer to: **http://www.ec.gc.ca/epe-epa/default.asp?lang=En&n=0B904C67-1**

In summary, the intended results from the PA will be achieved through the substance and product based actions being proposed.

8.4 Monitoring of PBDEs

The Government of Canada has been monitoring PBDEs in the Canadian environment and in landfills and wastewater treatment plants under the Chemicals Management Plan since 2008. This monitoring information is being used to assess the progress and effectiveness of the risk management actions taken by the Government of Canada and to better understand potential environmental exposure from these sources. The media being monitored include wildlife, fish, air and sediment. Biomonitoring of PBDEs is also underway to continue to monitor levels of PBDEs in humans, including vulnerable populations such as pregnant women and northern communities.

Furthermore, the National Pollutant Release Inventory (NPRI)[21] Program of the Government of Canada has collected data on decaBDE since 1994. The NPRI is Canada's legislated, publicly accessible inventory of pollutants released, disposed of and sent for recycling by facilities across the country. Industrial, institutional and commercial facilities which meet NPRI reporting requirements are required to report under the *Canadian Environmental Protection Act, 1999* (CEPA 1999). The program's main objectives are to inform the public, encourage voluntary reduction, monitor progress and set priorities for action.

8.5 Development of Federal Environmental Quality Guidelines (FEQGs) for PBDEs

The FEQGs provide benchmarks for the quality of the environment. The guidelines apply to indefinite exposures of wildlife and fishes to PBDE sources. The FEQGs are neither “never-to-be-exceeded” values nor effluent limits. FEQGs serve three functions: first, they can be an aid to prevent pollution by providing targets for acceptable environmental quality; second, they can assist in deciding the significance of concentrations of chemical substances currently found in the environment (monitoring of water, sediment and biological tissue); and third, they can serve as performance measures of the success of risk management activities.

The FEQGs for PBDEs were developed for water, sediment and fish tissue to protect aquatic life, bird, and mammalian consumers of aquatic life from adverse effects of PBDEs (Table 1). FEQGs developed directly from toxicity data relating to PBDEs were: water quality guidelines to protect aquatic life, the mammalian diet guidelines, and bird egg guidelines. Fish tissue guidelines for PBDEs were

[21] Further information on NPRI is available at **http://www.ec.gc.ca/pdb/npri/**

derived from the water quality guidelines; and, sediment quality guidelines were in turn derived from the fish tissue guidelines.

Table 1. Federal Environmental Quality Guidelines for Polybrominated Diphenyl Ethers

Homologue/ Formulation*	Congener	Water (ng/L)	Fish Tissue (ng/g ww)	Sediment** (ng/g dw)	Wildlife Diet[†] (ng/g ww food)	Bird Eggs (ng/g ww)
TrBDE	total	46	120	44	–	–
TeBDE	total	24	88	39	44	–
PeBDE	total	0.2	1	0.4	13 (bird)	29
	BDE-99	4	1	0.4	3	–
	BDE-100	0.2	1	0.4	–	–
HxBDE	total	120	420	440	4	–
HeBDE	total	17[‡]	–	–	64	–
OcBDE	total	17[‡‖]	–	6700[‖]	63[‖]	–
NoBDE	total	–	–	–	78	–
DeBDE	total	–	–	19[‖§]	9	–

*****FEQG for TrBDE, TeBDE, HxBDE , HeBDE, NoBDE and DeBDE are based on data for BDE-28, BDE-47, BDE-153, BDE-183, BDE-206, and BDE-209 respectively unless otherwise noted
**Values normalized to 1% organic carbon
[†]Applies to mammalian wildlife unless otherwise noted
[‡]Values based on a mixture of HeBDE and OcBDE
[‖]Values adopted from Screening Assessment Report (Environment Canada, 2006). Sediment values from the SAR appear different here because they have been normalized to 1% organic carbon
[§]Based on a mixture of DeBDE with some NoBDE

The guidelines will be used together with ongoing Canadian environmental monitoring to help assess the progress and effectiveness of risk management actions over time.

8.6 Development of a Risk Management Strategy for the Waste Sector Including PBDE-containing Products

The Government of Canada is developing a risk management strategy for the waste sector (i.e., landfills, incinerators and recycling facilities) that will include PBDE-containing products and other toxics at end-of-life. This strategy will aim to minimize the quantities of PBDEs released to the Canadian environment through the disposal or recycling of products containing PBDEs. As part of the development of one of these strategies, the Government of Canada is presently collecting information on waste and recyclable materials processing facilities in Canada.

Under the Stockholm Convention, the work program will address issues related to the recycling and reuse of products. This information will be used to further domestic actions already underway.

9. PROPOSED CONSULTATION APPROACH

A consultation document which provides details on the proposed risk management controls for PBDEs, as outlined in this risk management strategy, is anticipated to be published in 2010. A 60 day public comment period as well a stakeholders public meeting will follow publication of the consultation document.

The development of the regulatory controls to address manufactured and imported products containing PBDEs as well as additional substance based controls for PBDEs will follow the Government of Canada regulatory process, including publication in the *Canada Gazette*, Part I for further consultation.

10. NEXT STEPS / PROPOSED TIMELINE

Risk Management Strategy for PBDEs 2010

Actions	Date
Publication of the final revised Risk Management Strategy for PBDEs	August 28, 2010

Additional regulatory controls for tetra-, penta-, hexa-, hepta-, octa-, nona- and decaBDE congeners

Actions	Date
Publication and formal comment period on the Proposed Risk Management Controls for Polybrominated Diphenyl Ethers Consultation Document	2010
Consultation and Information gathering	2010-2011
Publication of the proposed PBDE regulatory controls in the *Canada Gazette*, Part I (CGI)	2012
Formal comment period on the proposed regulatory controls (CGI)	2012
Publication of the final regulatory controls in the *Canada Gazette*, Part II	2013

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