Government of Canada Gouvernement du Canada

Canada

EVALUATION OF THE EFFECTIVENESS OF RISK MANAGEMENT FOR POLYBROMINATED DIPHENYL ETHERS (PBDES)

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Environment and Climate Change Canada
Public Inquiries Centre
12th Floor, Fontaine Building
200 Sacré-Coeur Boulevard
Gatineau QC K1A 0H3
Telephone: 819-938-3860
Toll Free: 1-800-668-6767 (in Canada only)
Email: ec.enviroinfo.ec@canada.ca

Aussi disponible en français

Executive Summary

Polybrominated diphenyl ethers (PBDEs) are a group of chemical substances that are listed as toxic to the environment under the Canadian Environmental Protection Act. This group, which consists of seven PBDE substances (tetraBDE, pentaBDE, hexaBDE, hepaBDE, octaBDE, nonaBDE, and decaBDE), has been assessed by Health Canada and Environment and Climate Change Canada.

PBDEs do not occur naturally. In Canada and globally, commercial mixtures of PBDEs are used as flame retardants to slow the start and spread of fire. They are added to a variety of products, such as construction materials, plastics, polyurethane foam, textiles, furniture, automotive parts, electronics and electrical equipment.

PBDEs enter the environment through air, water and soil. This can happen when the chemicals are manufactured, when they are added to products, and when those products are used and disposed of after their use. Once released to the environment, they can remain in soil and sediment for long periods and can travel large distances through the air. PBDEs are highly toxic to fish and other wildlife. Because they accumulate in tissues of living organisms, animals that eat other animals have higher levels of PBDEs in their bodies. PBDEs are known as a type of persistent organic pollutants (POPs).

Environment and Climate Change Canada has worked to protect the Canadian environment from the harmful effects of PBDEs for over a decade. Canada has put in place regulations to prevent the manufacture, import and sale of PBDEs, with the exception of manufactured items[1] (i.e., finished products). This report describes the progress made to reduce the concentration of PBDEs in the Canadian environment. It outlines trends in environmental concentrations and discusses the actions taken by Environment and Climate Change Canada, as well as the overall performance of these actions. The report presents the following conclusions:

1. **Steady progress is being made towards preventing PBDE use and releases in Canada. However, more time is required to see the impact of recent and future amendments to the *Prohibition of Certain Toxic Substances Regulations, 2012* (PCTSR).**
    - Canadian industries and businesses have complied with current legal requirements that restrict the manufacture, import and sale of PBDE substances. Upcoming amendments to the PCTSR will restrict the import, manufacture, use, and sale of products that contain PBDEs.
    - Environmental monitoring results have shown decreases in levels of PBDEs in air, sediment, and fish. However, when compared to the Federal Environmental Quality

[1] A manufactured item is a product formed into a specific physical shape or design during its manufacture and that has, for its final use, a function or functions dependent in whole or in part on its shape or design (as defined in section 3- Definitions, paragraph f under the definition for “substance” under Canadian Environmental Protection Act, 1999).

Guidelines[2] (FEQGs) for these media, environmental levels of pentaBDE and decaBDE were found above their respective FEQG values in some sites. In addition, continued global use of PBDEs are a concern. Continued environmental monitoring is therefore required to determine if further reductions in the environment occur.

2. **Canada's continued cooperation and leadership in international initiatives on PBDEs and related national initiatives is required, as PBDEs continue to enter Canada through long-range transport and the import of products.**
    - PBDEs were designated as chemicals of concern under the Great Lakes Water Quality Agreement, and a binational strategy for PBDEs was developed. Under this strategy, Canada has identified several actions to further reduce PBDEs in the Great Lakes.
    - As a party, Canada complies with the Stockholm Convention on Persistent Organic Pollutants. TetraBDE, pentaBDE, hexaBDE, heptaBDE, and decaBDE are listed in the treaty as substances for elimination.
    - Nationally, environmental monitoring and research under the Whales Initiative is being conducted to understand and quantify the various sources of chemical pollutants. Pollutants such as PBDEs are threats to endangered whales.

3. **After the amended PCTSR are in place, further reductions of releases of PBDEs to the environment are expected to help meet the objectives of the Risk Management Strategy for PBDEs.**
    - The upcoming amendments under the PCTSR are expected to address the risks from the use and disposal of products containing PBDEs, including recycled materials. Performance measurement will continue to be a useful tool for compiling and analyzing information on the effectiveness of managing the risks of PBDEs.

This report recommends that the Government of Canada continue to focus its efforts on the following:

- monitoring PBDE releases and levels in the environment;
- managing risks associated with PBDEs (in particular, those related to products containing PBDEs);
- communicating with the public on the environmental risks of PBDEs in products and Canada's related risk management actions; and
- engaging nationally under the Whales Initiative and internationally under the Great Lakes Water Quality Agreement and the Stockholm Convention.

[2] Federal Environmental Quality Guidelines are recommendations for concentrations of a chemical substance in different media in the environment (example: water, soil, sediment, or animals). When environmental levels are below these concentrations, it is expected that there is a low likelihood of harmful effects.

Introduction

Polybrominated diphenyl ethers (PBDEs) are a group of chemical substances that are listed as toxic to the environment under the *Canadian Environmental Protection Act* (CEPA). This group consists of seven PBDE substances: tetraBDE, pentaBDE, hexaBDE, heptaBDE, octaBDE, nonaBDE, and decaBDE. The purpose of this report is to measure the effectiveness of the Government of Canada's actions in reducing the concentration of PBDEs in the environment.

PBDEs are not naturally found in the environment. They are used as flame retardants to slow the start and spread of fire. PBDEs are added to various products, such as construction materials, plastics, polyurethane foam, textiles, furniture, automotive parts, electronics, and electrical equipment.

1.1 The screening assessment reports and risk management strategy for PBDEs

The Government of Canada assessed all seven PBDEs in 2006 and concluded that all seven PBDEs pose a risk to the environment. PBDEs do not pose a risk to human health, since human exposure is currently not at a level of concern. TetraBDE, pentaBDE and hexaBDE also meet the criteria for persistence and bioaccumulation under the *Persistence and Bioaccumulation Regulations* of CEPA, which means that even small amounts of PBDEs released can remain in the environment for many years, accumulate in organisms, and continue to have harmful effects to the environment long after release.

HeptaBDE, octaBDE, nonaBDE and decaBDE may break down into tetraBDE, pentaBDE, or hexaBDE within animal tissue or by microbial decay (biotransformation). These PBDEs are of more concern than other PBDEs as they stay in the environment for long periods and become available to fish and wildlife.

When eaten or inhaled, the PBDE remains in an animal's tissue and levels build up over time as the animal continues to be exposed to the substance (bioaccumulation). In addition, levels of the PBDE have been found to increase when moving up the food web, which is a system of inter-related food chains (biomagnification). Animals that eat other animals have higher levels of PBDEs in their bodies. Within the organism, PBDEs can negatively affect brain, hormone and liver function, and thereby the growth and development of wildlife.

PBDEs tend to stay unchanged for longer periods in cooler environments than in warmer climates. This can mean that the substances may stay in the food web longer in these climates, and as a result, many future generations of Canadian fish and wildlife will be exposed to and suffer from delayed growth and development. This is why PBDEs are known as a type of persistent organic pollutant (POP).

An ecological state of the science report was published in 2010, after new information was received on decaBDE. This report confirmed the risks described in the original 2006 screening assessment report and identified that decaBDE, like tetraBDE, pentaBDE and hexaBDE, also bioaccumulates in the tissues of animals. Therefore, the risk posed to the environment by decaBDE is greater than was previously understood. In 2012, a second state of the science report was published, focusing on human health. This report confirmed the 2006 human health risk assessment conclusion that PBDEs are not toxic to human health.

All seven PBDEs are found in different proportions in three commercial mixtures: PentaBDE, OctaBDE, and DecaBDE (see Appendix, Table 3). PentaBDE and OctaBDE are no longer available worldwide but may be present in older or recycled materials or in products (made before 2006) that are still in use or imported into Canada (Environment Canada 2010b). Canada phased out the use of DecaBDE in 2013. Manufacturers of products have been seeking alternatives, since similar actions have taken place in the European Union and the United States (European Commission, 2007; USEPA, 2017).

PBDEs can be released from products when they off-gas to the air and into house dust, and into wash or rinse water when these products are cleaned. PBDEs can be further released to the environment through disposal. Dust and products in landfills can break down, leading to PBDEs in landfill leachate, which can end up in soil and water. Wash water and landfill leachate sent to wastewater treatment facilities can lead to PBDEs reaching rivers and lakes. All PBDEs can travel through air and be deposited far away from the location where they were first released. This is why PBDEs are both a local and global concern.

In 2010, Environment and Climate Change Canada published a revised Risk Management Strategy for Polybrominated Diphenyl Ethers (PBDEs) (the Strategy) (Environment Canada, 2010b). The Strategy outlined actions to address the ongoing risks of PBDEs. The environmental objective- a statement describing what should be achieved to address risks from PBDEs- was to protect the Canadian environment from the seven PBDEs by reducing amounts in the environment to the lowest levels possible. The risk management objective was to prevent PBDEs from being manufactured in or imported into Canada and to minimize releases of PBDEs to the Canadian environment.

1.2 Substance-based performance measurement

In 2009, the Commissioner of the Environment and Sustainable Development published a review of federal action on toxic substances. This review pointed out that the Government of Canada "lacks a systematic process for periodically assessing progress made in managing the risks of toxic substances". PBDEs was one of the groups of substances mentioned in the report with respect to performance measurement.

In response to this review, Environment and Climate Change Canada and Health Canada committed to evaluate the performance of risk management of substances declared toxic under *the Canadian Environmental Protection Act*, and have created a strategy for doing so. This kind of evaluation assesses the progress made in reducing the risks posed by a chemical substance, and includes the results from monitoring environmental or human exposure to the substance.

This current report evaluates the overall performance of actions taken to manage the risks of all seven PBDEs, and whether progress has been made in achieving the environmental objective in order to protect Canada's environment from the harmful effects of PBDEs.

2 Releases of PBDEs to the environment

PBDEs are released to the environment through several routes. Releases can occur when manufacturing PBDEs, and when manufacturing products containing PBDEs (Environment Canada, 2006). Once these products are on the market, releases of PBDEs continue to occur over the lifecycle of the product and after the product's disposal.

2.1 Industrial emissions and releases of decabromodiphenyl ether (decaBDE)

PBDEs have been released mainly through the lifecycle of products in Canada. However, decaBDE has also been released to the environment when products containing PBDEs are manufactured. Canadian industries have been reporting industrial releases of decaBDE through Canada's National Pollutant Release Inventory (NPRI) since 1994.

After the PentaBDE and OctaBDE commercial mixtures were phased out in 2004, industries started using the DecaBDE commercial mixture more frequently as a replacement. The increased use of the DecaBDE commercial mixture was likely the reason for the peak in 2006 (Figure 1).

Prior to 2006, approximately 80 to 90 percent of decaBDE used in Canada was for manufacturing electrical and electronic equipment and about 10 to 20 percent was used in textiles (Cheminfo, 2008).

The decrease of decaBDE releases between 2006 and 2013 was likely due to new evidence in the state of the science report relating to risks posed by decaBDE, and negotiations between the manufacturers of the DecaBDE commercial mixture with the Governments of Canada and the United States to phase it out by 2013. In anticipation of this phase-out of the DecaBDE commercial mixture, the manufacturers may have begun slowing down the production, sale, and export of it before 2010- the year that the producers announced a voluntary phase out of DecaBDE commercial mixture production, sales and exports. As Figure 1 shows, all industrial releases stopped by 2013.

The vast majority of releases of decaBDE were to off-site disposal facilities and off-site recycling, likely due to waste generated in making products from materials that already contain decaBDE.

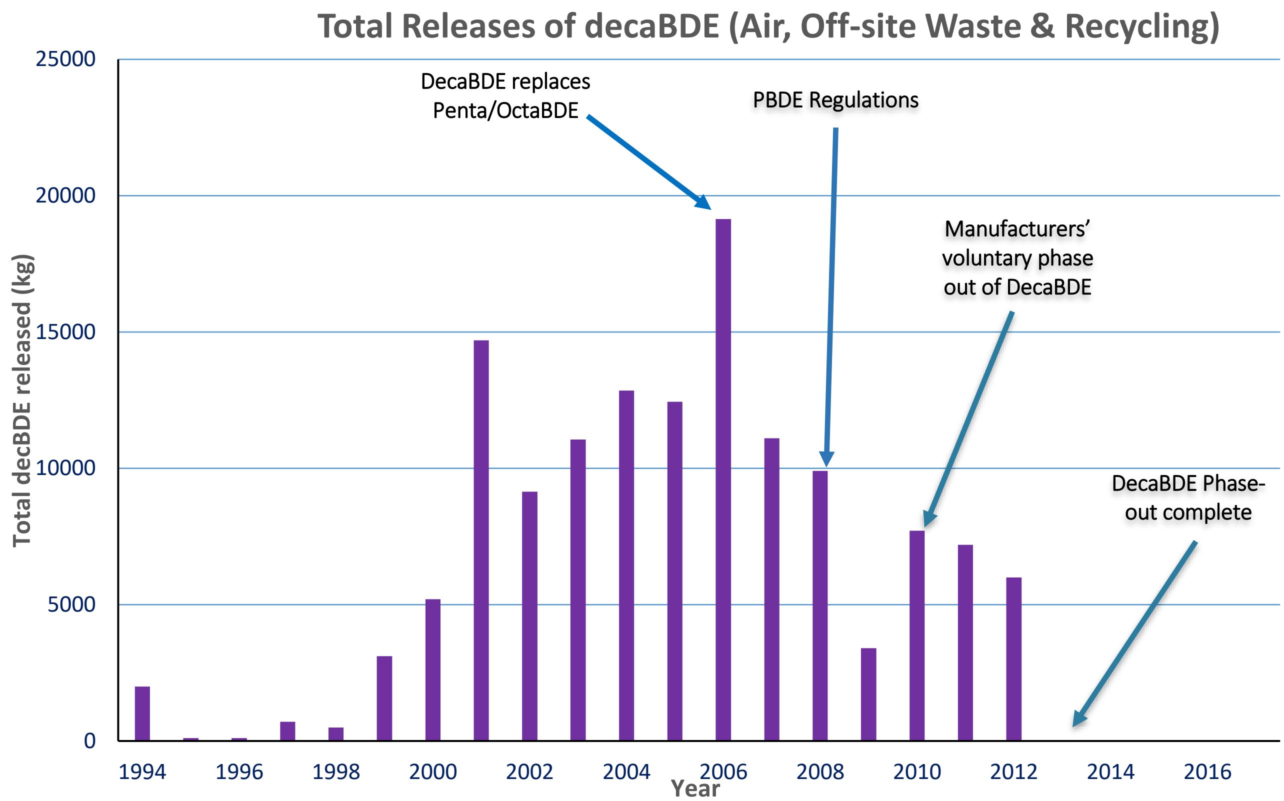


Figure 1. Total releases of decaBDE to the environment. Releases include those to air, off-site waste disposal, and off-site recycling. (National Pollutant Release Inventory 2020.)

Long description for the visually impaired:
Figure 1 represents the total releases of decaBDE reported to the National Pollutant Release Inventory (NPRI) to the environment from air, off-site waste disposal and off-site recycling. Since 1995, decaBDE releases had increased significantly and peaked in 2006 at 19,150 kilograms, when the DecaBDE commercial mixture replaced the PentaBDE and OctaBDE commercial mixtures. Between 2006 and 2013 there was a sharp decline in decaBDE releases. The PBDE Regulations were introduced in 2008 and manufacturers of the DecaBDE commercial mixture voluntarily phased out its production between 2010 to 2013. As of 2013, little to no releases of decaBDE were reported under the NPRI.

2.2 Releases of PBDEs from products to landfills and wastewater in Canada

Releases from solid waste and wastewater effluents are common ways for many chemicals to enter the environment. Once products containing PBDEs reach the end of their life, their disposal may result in PBDEs being released to soil either by release of landfill leachate (water that accumulates in landfills that contain chemicals) or by the application of treated wastewater biosolids (solid residues remaining after wastewater treatment) as fertilizer to agricultural land. Wastewater treatment of water containing PBDEs cannot remove all PBDEs, therefore treated wastewater effluents and landfill leachate can also release PBDEs to surface water[3]. In addition, some wastewater treatment plants take in landfill leachate for treatment and release it to surface water after treatment. For these reasons, this section reviews waste and wastewater streams together.

While incineration of solid waste is a possible source of emissions of PBDEs to air, it represents less than five percent of solid waste disposal in Canada. Therefore, it is not a significant source of PBDE release to the environment (ToxEcology Environmental Consulting, 2003).

Environment and Climate Change Canada conducted a study between 2008 and 2011 to determine levels of PBDEs and other chemicals found in landfill leachate. The study looked at treated and untreated leachate samples at 12 landfills to see if treatment resulted in reduced PBDE levels. The landfills in this study mostly receive municipal waste, some industrial waste, recycled and composted residues, and biosolids. This study assessed whether PBDE levels increased or decreased in leachate over the study's three-year duration.

It was found that midpoint (median) values for PBDE levels in treated landfill leachate were almost ten times lower than midpoint values for untreated leachate concentrations. On average, on-site treatment removed 66% of total PBDEs in the leachate. This removal rate stayed the same during the 2008 to 2011 sampling years. Overall, the study showed that PBDE concentrations were low in leachate and could be further reduced through treatment.

Looking at trends over the three years, the levels of PBDEs appeared to stay the same at eight of the twelve sites. PBDE levels in untreated leachate samples had increased between 2008 and 2011 for two of the landfill locations. For the two remaining sites, there was not enough data to assess if there were increases or decreases in overall PBDE levels.

In 2018, Environment and Climate Change Canada conducted sampling of landfill leachate at four large municipal landfills in Southern Ontario. Samples were tested for flame retardants containing bromine, or chlorine atoms, which included all PBDEs. The study aimed to better understand typical levels and types of PBDEs found in the leachate of a typical landfill before it was sent to municipal wastewater treatment plants.

All seven PBDEs were detected in the samples. The top three levels of PBDEs in leachate were for tetraBDE, pentaBDE, and hexaBDE, with pentaBDE having the highest concentration in the leachate samples. As the study sampled leachate for only one year at these four landfills, follow-up monitoring every three to five years would be helpful to determine any long-term trends.

With respect to wastewater, from 2009 to 2010 Environment and Climate Change Canada sampled nineteen wastewater systems, which represented typical wastewater treatment processes in Canada. The purpose of the study was to determine which type of wastewater

[3] Surface water refers to water in rivers and streams in contrast to aquifers and ground water

treatment (i.e., primary, secondary, lagoon, etc.) was best at removing PBDEs. Municipal systems were sampled, as well as systems on federal and Indigenous lands.

The results indicated that the midpoint value for total PBDE concentrations in untreated wastewater across all wastewater systems was fourteen times higher than concentrations for treated wastewater, regardless of treatment type.

Two-phase wastewater treatment systems that remove dissolved and fine particulate organic materials in the wastewater had the highest removal rates (87% to 98%). One-phase wastewater treatment systems that use chemicals or aeration to treat the wastewater had lower removal rates of PBDEs and varied highly between systems (61% to 90% and 66% to 98%, respectively). The individual PBDEs most frequently found in the wastewater that make up the percentage of the total PBDE levels were tetraBDE (26%), pentaBDE (27%), nonaBDE (9%) and decaBDE (28%).

PBDE concentrations were also measured in wastewater solids, including primary sludge, waste biological sludge, and treated biosolids. In general, solids concentrations are approximately a thousand times higher than wastewater concentrations, showing that PBDEs tend to stay in solids during wastewater treatment. The individual PBDEs found most frequently in treated biosolids as a percentage of total PBDE levels were tetraBDE (17%), pentaBDE (19%), nonaBDE (9%) and decaBDE (48%).

2.3 Conclusion for releases of PBDEs to the environment

The declining trend from 2006 to 2018 of decaBDE industrial releases is evidence that Canadian industries have made efforts to discontinue importing, selling and using the DecaBDE commercial mixture.

Although preliminary, the landfill leachate and wastewater studies provided some understanding concerning levels of PBDEs that are usually found in landfill leachate and untreated wastewater (i.e., releases from products). The studies also confirmed that systems with two phases of wastewater treatment for removing organic materials from effluent (i.e. secondary biological treatment) provide the most effective available treatment option for removal of PBDEs before their release to surface water.

3 Levels of PBDEs in the environment (air, water, sediment, biota)

To establish whether the risk management actions were effective in meeting the Strategy’s objectives, Environment and Climate Change Canada conducted environmental monitoring in air, water, sediment and certain species of wildlife (biota). Several years of data were required to observe significant changes of PBDE levels in the environment. This section compares PBDE levels measured in water, sediment and biota to the levels recommended in the Federal Environmental Quality Guidelines (FEQGs) for PBDEs, which were developed in 2013 (Table 1). When environmental levels are below these guidelines, it is expected that there would be a low risk of harmful effects.

There is no FEQG for air because air quality is managed under Canada's Air Quality Management System, using the Canadian Ambient Air Quality Standards. Monitoring air concentrations for PBDEs is useful to measure reductions, for modelling, and to compare concentration levels between countries or regions.

Table 1. Federal Environmental Quality Guidelines for Polybrominated Diphenyl Ethers (PBDEs) (2013)

Federal Environmental Quality Guidelines for PBDEs						
Homologue	**Congener**	**Water (ng/L)**	**Fish Tissue (ng/g ww)**	**Sediment (ng/g dw)**	**Wildlife Diet (ng/g ww food source)**	**Bird Eggs (ng/g ww)**
triBDE	total	46	120	44	–	–
tetraBDE	total	24	88	39	44	–
pentaBDE	total	0.2	1	0.4	3 (mammal) 13 (birds)	29
pentaBDE	BDE-99	4	1	0.4	3	–
pentaBDE	BDE-100	0.2	1	0.4	–	–
hexaBDE	total	120	420	440	4	–
heptaBDE	total	17	–	–	64	–
octaBDE	total	17	–	5600	63	–
nonaBDE	total	–	–	–	78	–
decaBDE	total	–	–	19	9	–

For more information on how the FEQGs were developed for each PBDE in each environmental medium, please consult the FEQGs for PBDEs.

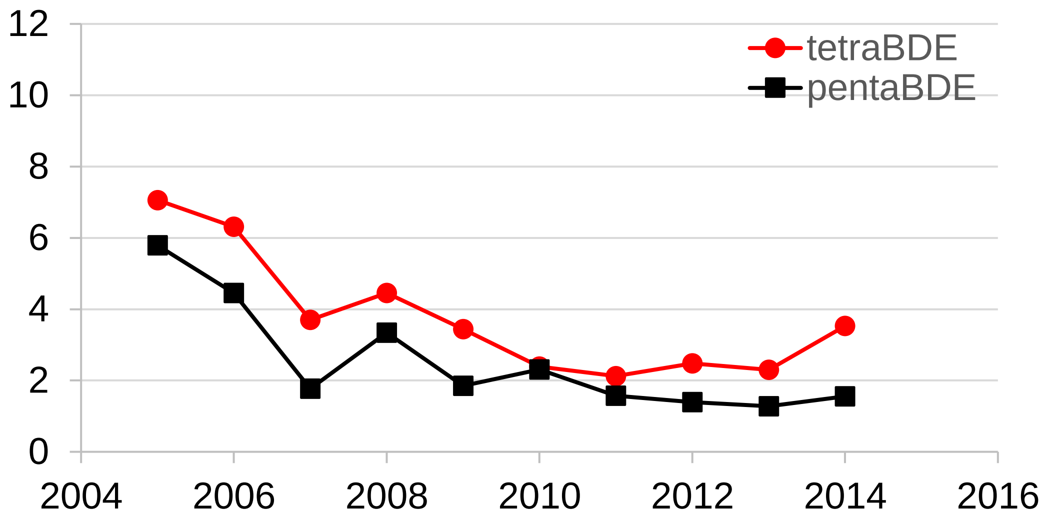
Although all PBDEs were monitored in environmental media, only the results for tetraBDE, pentaBDE, hexaBDE, and decaBDE will be discussed in this report. These PBDEs are the most prevalent in the PentaBDE, OctaBDE, and DecaBDE commercial mixtures, and therefore, in finished products containing PBDEs. Also, due to the chemical properties of tetraBDE, pentaBDE, and hexaBDE, these three substances have remained in the environment several years after the commercial mixtures were phased out in Canada. The FEQG for pentaBDE is more stringent for fish and wildlife diet media because pentaBDE has a higher bioaccumulation and biomagnification rate. Also at the time, FEQGs for bird eggs for pentaBDE were developed based on the best available toxicity data, but such data was not available for the other PBDE substances.

3.1 Air

Several locations across Canada were monitored over a number of years for PBDE levels in air. This report focuses on the results from three locations: Point Petre, Ontario; Burnt Island, Ontario; and Alert, Nunavut.

Point Petre is located by Lake Ontario (near Kingston), and represents a location near urban and industrial areas, such as Toronto. Air monitoring occurred at this location from 2005 to 2014. During this period, annual concentrations of tetraBDE and pentaBDE decreased relatively quickly (Figure 2a). Apart from a slightly higher air concentration in 2008, concentrations of decaBDE were slow to decline at Point Petre compared to the tetraBDE and pentaBDE levels. This slower decrease could be due to the DecaBDE commercial mixture phase out occurring later (2013) than the PentaBDE and OctaBDE phase outs (2004) (Shunthirasingham et al. 2018). The trend for decaBDE in Point Petre from 2010 onward varied from year to year (Figure 2b) and could be the result of products in use or circulation in urban areas such as Toronto, Ontario, that contain the DecaBDE commercial mixture.

A.



B.

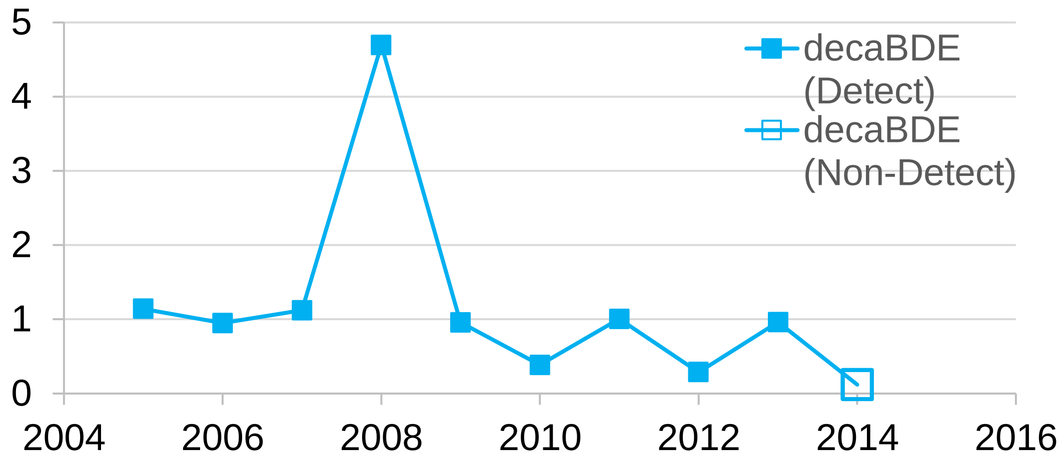


Figure 2 (a and b), Trends of midpoint air concentrations of tetraBDE and pentaBDE (a) and decaBDE (b) from Point Petre, Ontario from 2005 to 2014. Concentrations are in pg/m^3.

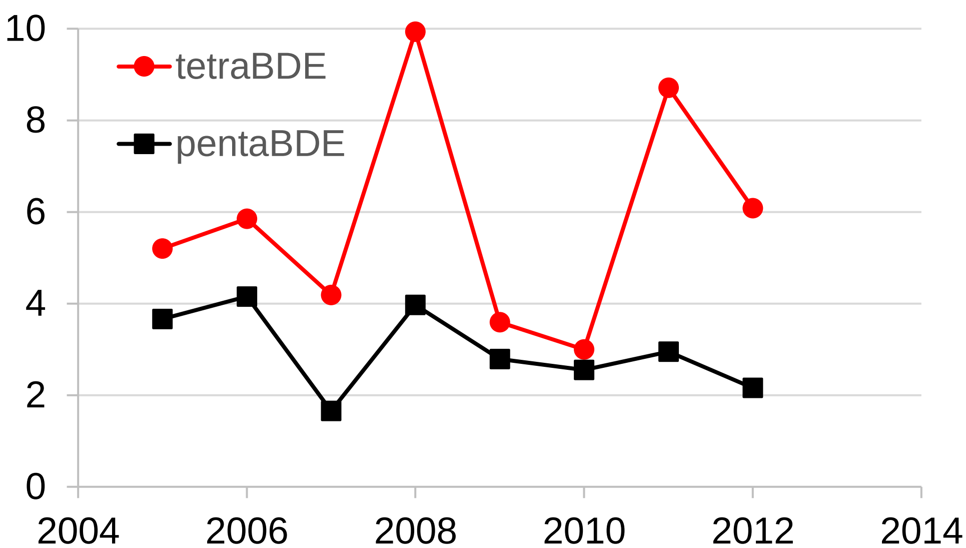
Long description for the visually impaired:
Figure 2a shows the trends for mid-point air concentrations of tetraBDE and pentaBDE from 2005 to 2014 taken at Point Petre, Ontario. The graph shows a steady downward trend for both tetraBDE and pentaBDE. The tetraBDE curve ranged from seven picograms per metre cubed in 2005 to two picograms per metre cubed in 2011. Air concentrations of tetraBDE rose slightly to 3.8 picograms per metre cubed between 2011 and 2014. There was a steady decline of pentaBDE air concentrations, ranging from six picograms per metre cubed in 2005 to 1.8 picograms per metre cubed in 2014.

Figure 2b shows the trend for mid-point air concentrations of decaBDE from 2005 to 2014 for air samples also taken at Point Petre. Concentrations declined ranging from 1.2 picograms per metre cubed in 2005 to a not detectable concentration in 2014, although there was an anomalous concentration peak in 2008 where the concentration was at 4.8 picograms per metre cubed.

Burnt Island, Ontario, is located by Lake Huron and represents a more remote location. The industrial and mining activities in Sudbury and Sault Ste. Marie may have an influence on PBDE levels at this location. Monitoring results indicated that tetraBDE concentrations varied somewhat, yet there was no overall decrease. The concentration of pentaBDE decreased more slowly over time at Burnt Island compared to Point Petre (Figure 3a), which indicates that there is a time lag between the cease in use of the PentaBDE commercial mixture and a decrease in air concentrations in Burnt Island.

DecaBDE concentrations decreased relatively quickly at Burnt Island as decaBDE is a heavier chemical that tends to attach to air dust particles, and settles out of the atmosphere more quickly (Figure 3b). Therefore, the air concentrations of decaBDE observed are likely based on local sources in Burnt Island.

A.



B.

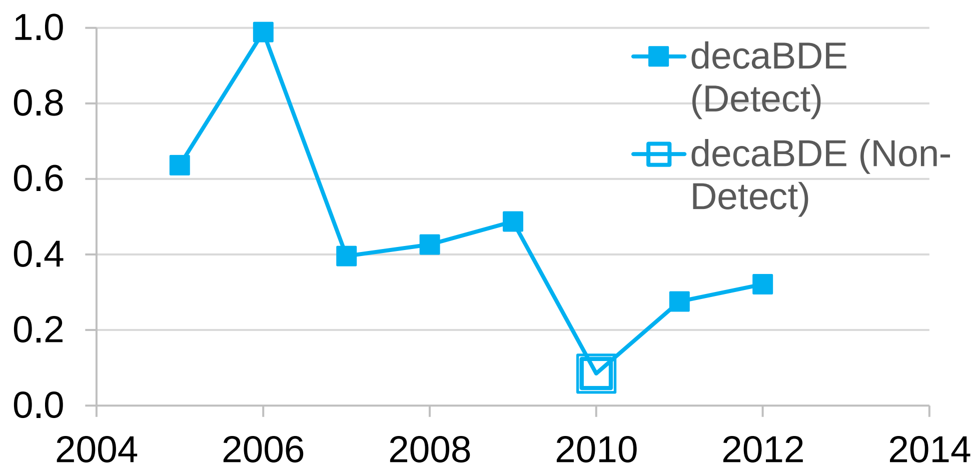


Figure 3 (a and b), Trends of midpoint air concentrations of tetraBDE and pentaBDE (a) and decaBDE (b) from Burnt Island, Ontario from 2005 to 2012. Concentrations are in pg/m^3.

Long description for the visually impaired:
Figure 3a shows the trend for mid-point air concentrations of tetraBDE and pentBDE from 2005 to 2012 for air samples taken at Burnt Island, Ontario. The graph shows that there was no overall trend in the concentrations for tetraBDE, with concentrations varying from year to year between 3 picograms per metre cubed to 10 picograms per metre cubed. PentaBDE concentrations declined slowly between 4.1 picograms per metre cubed in 2006 to 2.1 picograms per metre cubed in 2012.

Figure 3b shows the mid-point air concentrations for decaBDE at Burnt Island Ontario were 1 picogram per metre cubed or below and continued a declining trend from 2006 to 2012.

Alert, Nunavut, was chosen to represent a remote, northern, location and to observe long-range transport patterns of PBDEs. Samples were taken between 2002 and 2015. Levels of most PBDEs were unchanged in air between 2002 and 2010 with the exception of two peaks in 2006 and 2010, which could be due to PBDEs in products that were used on a nearby military base. However, the data for the years 2011 to 2015 show that the concentrations of most PBDEs decreased with time (Hung et al, 2016; Figure 4a and b). Another reason for unchanged levels in the earlier years could be due to higher historical usage of PBDEs in North America, resulting in long-range transport and deposition of PBDEs in the Arctic from other parts of North America (Hung et al. 2016).

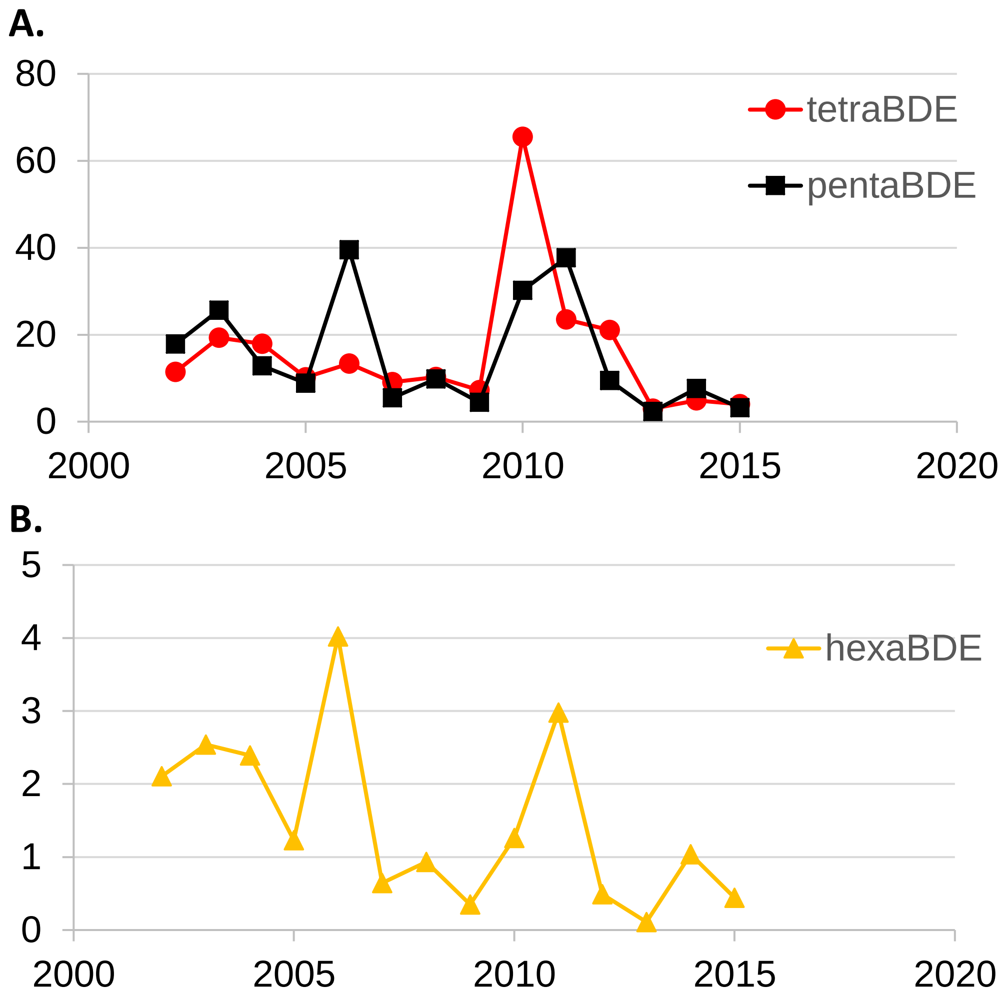


Figure 4 (a and b), Trends of maximum air concentrations of tetraBDE and pentaBDE (a) and hexaBDE (b) from Alert, Nunavut from 2002 to 2015. Concentrations are in pg/m^3.

Long description for the visually impaired:
Figure 4a shows the maximum air concentrations for tetraBDE and pentaBDE at Alert, Nunavut. The trend showed an overall decline between 2002 and 2015, with anomalous peaks for tetraBDE in 2011 where air levels were at 67 picograms per metre cubed. Anomalous peaks were found for pentaBDE levels in 2006 and 2011 where levels reached 40 picograms per metre cubed for both years.

Figure 4b shows the maximum air concentrations for hexaBDE at Alert, where there was an overall declining trend ranging from 4 picograms per metre cubed in 2002 and 0.4 picograms per metre cubed in 2015.

Air monitoring studies from the Global Atmospheric Passive Sampling (GAPS) Network have shown that global air levels of PBDEs did not decrease very much between 2005 and 2014.

Because PBDEs travel long distances in air, it may be assumed that there have not been significant decreases of PBDEs in air within Canada (Rauert et al. 2018).

3.2 Surface water

Environment and Climate Change Canada has sampled surface water[4] for PBDEs in British Columbia and Ontario since the 1990s. Water samples were taken in 2011 and 2012 at Lake Erie, Lake Huron, Lake Ontario and Lake Superior in Ontario. More recent water samples were taken in 2012 and 2013 at Beaver Creek (Vancouver Island), the Fraser River Basin, and the Columbia River Basin in British Columbia.

TetraBDE, pentaBDE, and decaBDE were the main PBDEs found in surface water in all locations monitored during these two sampling periods. This was expected, as these substances constitute the highest proportions of PBDEs found in each of the three PBDE commercial mixtures that were used in Canada (see Appendix, Table 3 for proportions).

The results indicate that PBDE concentrations near wastewater treatment plants and downstream of larger urban areas could be due to PBDE releases from products. As well, decaBDE releases from less populated locations, such as the locations sampled in the Columbia and Fraser River Basins in interior British Columbia, could also be due to releases of decaBDE contained in products.

However, PBDE levels in water were well below their FEQGs for surface water for all surface water samples.

3.3 Sediment

PBDEs are more easily detected in sediment than water because PBDEs do not easily dissolve in water and tend to be attracted to solid particles (sediment or organic matter). Therefore, bioaccumulation from organisms eating sediment is more of a concern than bioaccumulation from being exposed through water.

Monitoring of sediment occurred across Canada in ten river and lake basins[5] from 2007 to 2018. Levels for six PBDEs were analyzed (triBDE - for comparison, tetraBDE, pentaBDE, hexaBDE, octaBDE, and decaBDE). In sediment, the levels of triBDE, hexaBDE and octaBDE were below the FEQG levels in all locations.

However, for tetraBDE, pentaBDE, and decaBDE, some samples were above their respective FEQG levels. For tetraBDE, one of the ten locations had sediment levels above its FEQG. For

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[4] Surface water refers to water in rivers and streams in contrast to water in aquifers/ground water

[5] Sampled Basins include the Pacific Coast (British Columbia), Okanagan-Similkameen Lakes (Interior British Columbia), Columbia River (Interior British Columbia), Yukon River, Assiniboine-Red River (Manitoba), Lower Saskatchewan-Nelson River (Manitoba), Great Lakes Basin (Ontario), St. Lawrence River Basin (Quebec), Maritime Coast (Atlantic Provinces, except Newfoundland-Labrador), and Newfoundland-Labrador.

pentaBDE, eight of the ten locations had sediment levels above its FEQG. For decaBDE, three of the ten locations had sediment levels above its FEQG.

Although PBDEs in sediments have not been sampled long enough in many of the locations to show trends, Lake St. Pierre, Quebec, is a good example of changes of pentaBDE concentrations found in sediment over time (from 2003 to 2013). Average pentaBDE levels in sediment samples decreased over ten years, showing improvements in many areas of Lake St. Pierre to below the FEQG (Figure 5).

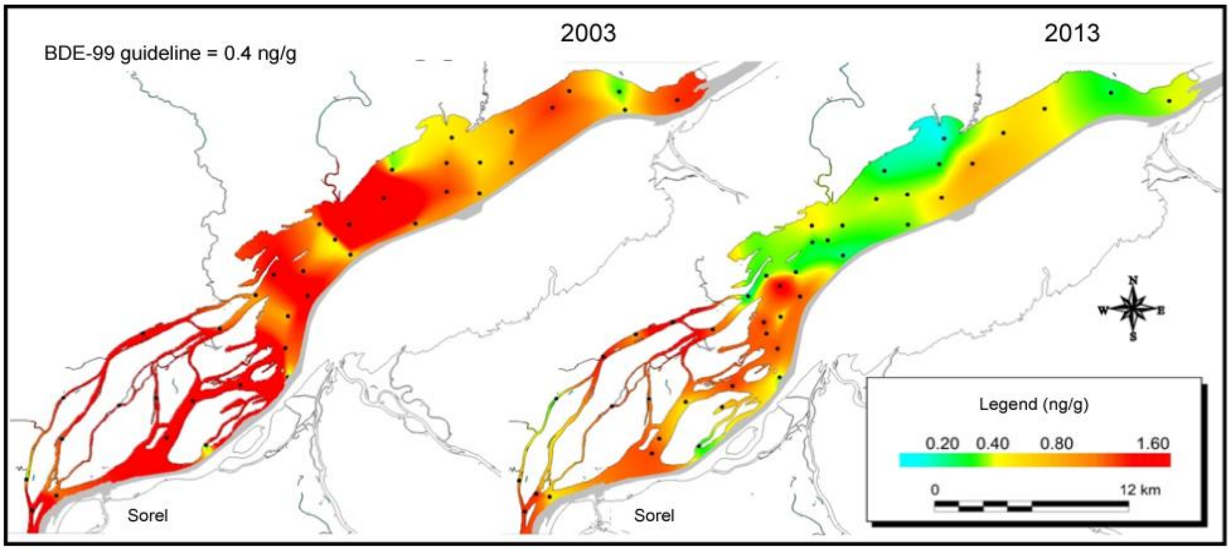

Figure 5. PentaBDE concentrations in sediments from Lake St. Pierre, Quebec, Canada, 2003 and 2013 (CESI 2020). The FEQG for pentaBDE is 0.4 ng/g (dry weight) is shown as yellow in the map. Concentrations shown in orange are about twice the FEQG and in red are four or more times above the FEQG. Concentrations in green shown in green are half the FEQG and in blue are below half of that level. The points represent sampling locations.

Long description for the visually impaired:
Figure 5 is a map showing the concentrations of pentaBDE for Lake St. Pierre in the St. Lawrence River for 2003 and 2013. For 2003, the area is almost entirely orange and red, corresponding to concentrations above 0.8 nanograms per gram. For 2013, the downstream area is predominantly blue and green, corresponding to concentrations below 0.5 nanograms per gram. The upstream area is primarily yellow and red, corresponding to concentrations above 0.8 nanograms per gram in the channels of the Berthier-Sorel Islands.

3.4 Fish and bird eggs

PBDEs bioaccumulate in animal tissue and biomagnify up the food chain, so it is essential to analyze tissue and egg samples for PBDEs to understand the extent and duration that PBDEs remain in wildlife even after releases to the environment no longer occur. For the purpose of this report, PBDE levels in fish tissue and bird eggs in selected locations will be discussed to illustrate overall trends.

Fish tissue
Environment and Climate Change Canada sampled and analysed fish tissue for levels of four PBDEs (triBDE, tetraBDE, pentaBDE, hexaBDE) from 2016 to 2018[6] in Canada. The fish that were studied were several species of trout and walleye, which are at the highest level in their food chain.

The monitoring results show that triBDE, tetraBDE, and hexaBDE concentrations were below each of their FEQG levels in all regions sampled. Specifically, in Lake Ontario, the sampling illustrated the declining trends of tetraBDE and pentaBDE concentrations in lake trout from 1997 to 2018 (Figures 6 and 7). As expected, pentaBDE concentrations remained above its FEQG level in all ten locations, because it persists in animal tissue longer than the other PBDEs.

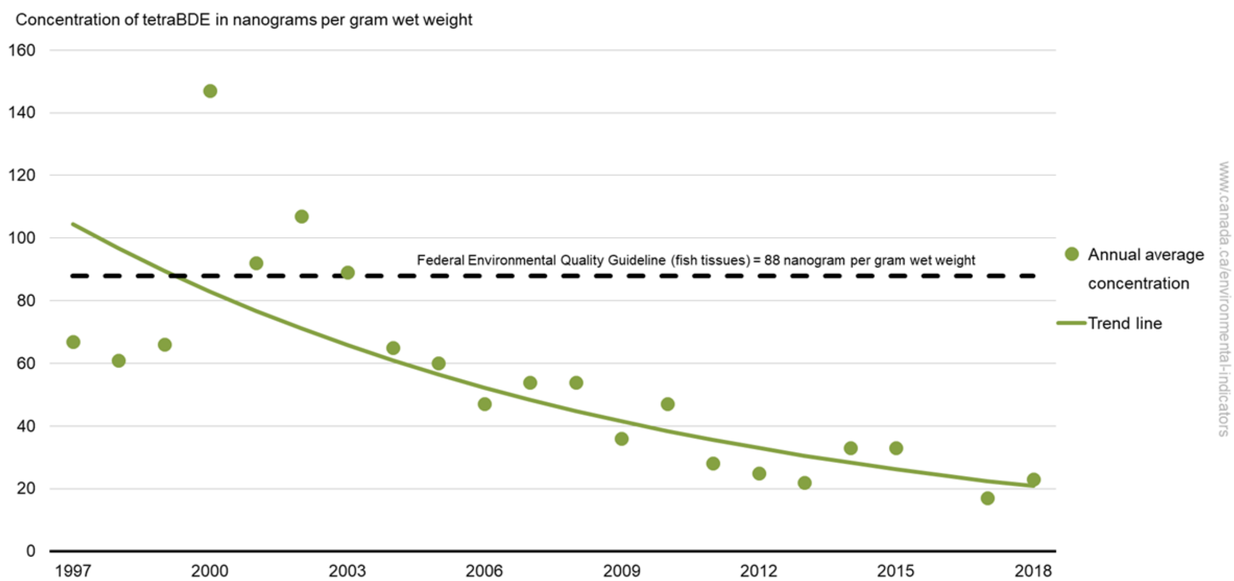

Figure 6. TetraBDE concentrations in Lake Trout from Lake Ontario, Canada, 1997 to 2018 (CESI, 2020)

Long description for the visually impaired:
This is a graph plotting tetraBDE concentrations in Lake trout from Lake Ontario . Each point on the graph shows tetraBDE concentrations expressed as an annual geometric average. A downward statistical trend is detected at the 95% confidence level for the time series. This trend is being compared to the Federal Environmental Quality Guideline (FEQG) for tetraBDE in fish tissue, which was developed and published in 2013 by Environment and Climate Change Canada. The FEQGs were developed to assess the ecological significance of levels of PBDEs in the environment.

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6 Sampled Basins include Columbia River (Interior British Columbia), Yukon River, Peace-Athabasca River (Alberta) Lower Mackenzie River (Northwest Territories) Assiniboine-Red River (Manitoba), Lower Saskatchewan-Nelson River (Manitoba), Churchill River (Manitoba) Great Lakes Basin (Ontario), St. Lawrence River Basin (Quebec), and Maritime Coast (Atlantic Provinces, except Newfoundland-Labrador).

Figure 7. PentaBDE concentrations in Lake Trout from Lake Ontario, Canada, 1997 to 2018 (CESI, 2020)

Long description for the visually impaired:
This graph plots pentaBDE concentrations in Lake Trout from Lake Ontario. Each point on the graph shows pentaBDE concentrations expressed as an annual geometric average. A downward statistical trend is detected at the 95% confidence level for the time series. This trend is being compared to the Federal Environmental Quality Guideline (FEQG) for pentaBDE in fish tissue, which was developed and published in 2013 by Environment and Climate Change Canada. The FEQGs were developed to assess the ecological significance of levels of PBDEs in the environment.

Bird eggs

PBDEs levels were monitored in bird eggs. Samples included two types of birds from across Canada: gulls (fish eaters) and European Starlings (eaters of land insects/animals). The eggs of Herring Gulls, California Gulls and Glaucous-winged Gulls were included to represent the eggs of “gulls”. The study compared differences in PBDE levels in bird eggs between urban and rural locations, as well as industrial, landfill and agricultural sites.

PBDE levels in gull eggs were generally higher near urban centers, compared to rural areas.

The eggs of European Starlings were collected in five urban areas near industrial and landfill sites. These urban sites were compared to five neighbouring agricultural areas. Within each urban center, PBDE concentrations were higher in eggs near landfill sites when compared to the industrial sites or to the agricultural areas. Eggs from industrial sites had higher levels of PBDEs than those in the neighbouring agricultural area. Similar results were found in starling eggs collected from these locations in 2009, 2010, and 2011 (Chen et al. 2013). The results show that wildlife living or eating in areas near landfills could be more affected by PBDE exposure than wildlife living or eating near industrial areas.

The main PBDEs found in bird eggs were tetraBDE, pentaBDE, and hexaBDE. This was expected as these PBDEs are highly bioaccumulative and similar results were found in fish tissue (Environment Canada 2006; Gandhi et al. 2006). Higher decaBDE levels were also observed, although they were lower than tetraBDE, pentaBDE, and hexaBDE levels.

PentaBDE levels exceeded its FEQG level in gull eggs at most locations in Canada, and in starling eggs for eggs taken near landfills and urban industrial locations.

Trends in monitoring results suggest that although there is considerable year to year variability, there have been patterns of decline of PBDEs in bird eggs over time, particularly for tetraBDE, pentaBDE, hexaBDE and heptaBDE. Bird egg decaBDE levels have varied considerably since 2005, so no clear trends could be observed.

For animals that eat bird eggs as part of their diet, tetraBDE, pentaBDE, hexaBDE, and decaBDE were above their FEQG levels in animals eating gull eggs at most locations. PentaBDE levels were above the FEQG in animals eating starling eggs at most locations. The concentrations of tetraBDE, hexaBDE, and decaBDE levels were only above their FEQG levels in animals eating starling eggs at select landfill and industrial sites. HeptaBDE levels were below the FEQG level for animals that eat both gull or starling eggs.

3.5 Conclusion for levels of PBDEs in the environment

Overall, the environmental monitoring data suggest there are decreasing trends in the levels of tetraBDE, pentaBDE, hexaBDE and decaBDE in air, surface water, sediment, fish, and bird eggs across Canada (Table 2). Despite declining levels, tetraBDE, pentaBDE and decaBDE levels remain above their FEQG levels for sediment, bird eggs and animals that eat bird eggs in most locations. PentaBDE levels in fish also remained above its FEQG level at all locations.

Table 2. Summary comparison of trends of monitored PBDE levels and the extent that levels have exceeded their FEQGs, by environmental media.

Comparison of measured PBDE Concentrations in environmental media to their Federal Environmental Quality Guidelines (FEQGs)		
Environmental Media	***Concentration trends/ tendencies***	***Concentration above or below FEQG***
Air	Decreasing	No FEQG available
Surface Water	Decreasing	Below
Sediment	Decreasing	Above
Fish	Decreasing	Below for most FEQGs except for pentaBDE

Bird eggs and animals that eat bird eggs	Decreasing for most; variable for decaBDE	Above for pentaBDE for bird eggs; mostly above for animals that eat bird eggs

4 Domestic approach: progress on actions in Canada

The *Risk Management Strategy for Polybrominated Diphenyl Ethers (PBDEs)* was published in 2009 and was revised in 2010, due to new evidence showing that decaBDE posed a higher risk to the environment than originally thought.

This section provides a summary of domestic actions and indicates whether the actions meet the risk management objective of the Strategy to prevent the manufacturing, import, use and sale of PBDEs in Canada.

4.1 Voluntary action by three primary suppliers of the DecaBDE commercial mixture on its production and export

The Government of Canada worked with the three major producers of the DecaBDE commercial mixture in the United States to develop a performance agreement to phase out the export and sales of the DecaBDE commercial mixture to Canada by 2013.

At the same time, the United States negotiated a similar phase out of the production, sale and use of the DecaBDE commercial mixture. As a result, in 2010, these producers voluntarily committed to phase out the manufacture of the DecaBDE commercial mixture in the United States, thereby phasing out exports and sales of it to electrical, electronic, transportation, military, furniture, textiles, and construction sectors by 2013.

The three producers confirmed that they achieved this goal by mid-2012, resulting in no need for a formal environmental performance agreement.

4.2 Regulatory action on PBDEs

Regulatory action has been in place since July 2008 and amendments are ongoing to further prohibit or restrict the manufacture, import, use and sale of PBDEs in Canada.

Polybrominated Diphenyl Ethers Regulations, 2008

The *Polybrominated Diphenyl Ethers Regulations, 2008* (PBDE Regulations) were put in place to prohibit the manufacture, and restrict the use, sale, or import of PBDE substances, with the exception of decaBDE. This meant that the manufacture and industrial use of the PentaBDE and OctaBDE commercial mixtures were prohibited once these regulations were in force. However, manufactured items (i.e., finished products) were exempted from these regulations.

Based on analyses of technical and socio-economic information collected in 2009, it was confirmed that all manufacturers had complied with the PBDE Regulations and that all Canadian industries that previously used the PentaBDE and OctaBDE commercial mixtures were no longer using them.

Because there was continued widespread global use of PBDEs (particularly decaBDE) and because finished products were exempted from these regulations, Environment and Climate Change Canada was concerned that prohibiting the PentaBDE and OctaBDE commercial mixtures was not sufficiently effective at reducing PBDE concentrations in the environment. Products containing these substances are used over many years and are either disposed of or recycled into materials to make new products in Canada. Product use, disposal or recycling would therefore result in continued releases of PBDEs to the environment.

Regulations Amending the Prohibition of Certain Toxic Substances Regulations, 2012
Given that current prohibitions under the PBDE Regulations needed to be extended to the manufacture, use, sale, and import of the DecaBDE commercial mixture, amendments to the *Prohibition of Certain Toxic Substances Regulations, 2012* (PCTSR) were published in 2016. The PCTSR aims to prohibit the manufacture, use, sale, or import of all seven PBDEs, with a limited number of exemptions, such as allowing imports of finished products that contain PBDEs into Canada. As a result, the PBDE Regulations were repealed.

The instrument's objective was to prevent the manufacture and import of PBDEs into Canada, and to minimize their releases into the environment from all Canadian sources (Environment Canada. 2010b).

The objective was met given that Canadian industries had already confirmed that they were no longer using any of the three PBDE commercial mixtures in their products.

Products-based controls for PBDEs and Waste Management of Materials Containing PBDEs
Although the PCTSR address the industrial use of PBDEs, the import, use, disposal or end-of-life use of imported finished products continue to be a concern, including the recycling and the re-use of materials that may contain high quantities of PBDEs.

Two consultation documents were prepared to propose regulatory action for products that contain PBDEs.

These included the Consultation Document on Proposed Risk Management for Products Containing PBDEs, which was published in September 2013 and the Consultation Document on Proposed Amendments to the Prohibition of Certain Toxic Substances Regulations, 2012 for PFOS, PFOA, LC-PFCAs, HBCD, PBDEs, DP and DBDPE, which was published in 2018.

Currently, additional proposed amendments to the PCTSR are underway to further restrict the manufacture, use, sale, and import of certain toxic substances, including PBDEs. The amendments would remove exemptions for the import, manufacture, use, or sale of PBDEs (except decaBDE) in finished products. Time-limited exemptions for decaBDE for the automobile sector would align with exemptions under the *Stockholm Convention for Persistent Organic Pollutants* (section 5.3).

The expected publication date for the draft amendments of the Regulations is fall 2020 and the final amendments are expected to be published in 2021. Compliance by regulated industries and businesses is required once the regulatory amendments enter into force.

In addition, a supporting initiative is underway, which aims to protect and support the recovery of Southern Resident Killer Whales, North Atlantic Right Whales and St. Lawrence-Estuary Belugas. The Southern Resident Killer Whales and St. Lawrence Estuary Belugas are particularly vulnerable to persistent organic pollutants, such as PBDEs. As such, Environment and Climate Change Canada is conducting environmental monitoring and research to understand and quantify the contributions of various sources of these land-based pollutants to the impacts on these animals.

4.3 Communicating with Canadians

The Government of Canada communicates with Canadians on PBDEs in the Canadian environment through the Chemical Substances portal and the CEPA registry portal. These sites provide information on environmental concerns related to PBDEs, products containing these substances, and the regulatory measures that the government has taken and plans to take. In August 2019, the Government of Canada published a Summary of flame retardant assessments and management conducted under the Canadian Environmental Protection Act, 1999 on the Chemical Substances Portal for industries and businesses involved with flame retardants, consumers, and the general public. The summary page aims to provide information to help industries and businesses make decisions about using different flame retardants. It is also a central location to find risk assessments, conclusions, and caution statements of flame retardants that have not been found to be of concern based on current exposure levels.

4.4 Conclusion for domestic approach: progress on actions

The regulatory approach for PBDEs includes phasing out and prohibiting the manufacture of all PBDEs; restricting the import, sale and use of all PBDE substances; and restricting products containing PBDEs (Figure 8). Once the upcoming PCTSR amendments are in force, it will take several years to assess whether all the regulatory and voluntary actions have been effective in minimizing releases of all PBDEs to the environment. This is because it will take time to phase out remaining products in use, including recycled materials containing PBDEs. PBDEs will also persist in the environment for years even after products containing PBDEs are no longer used in Canada.

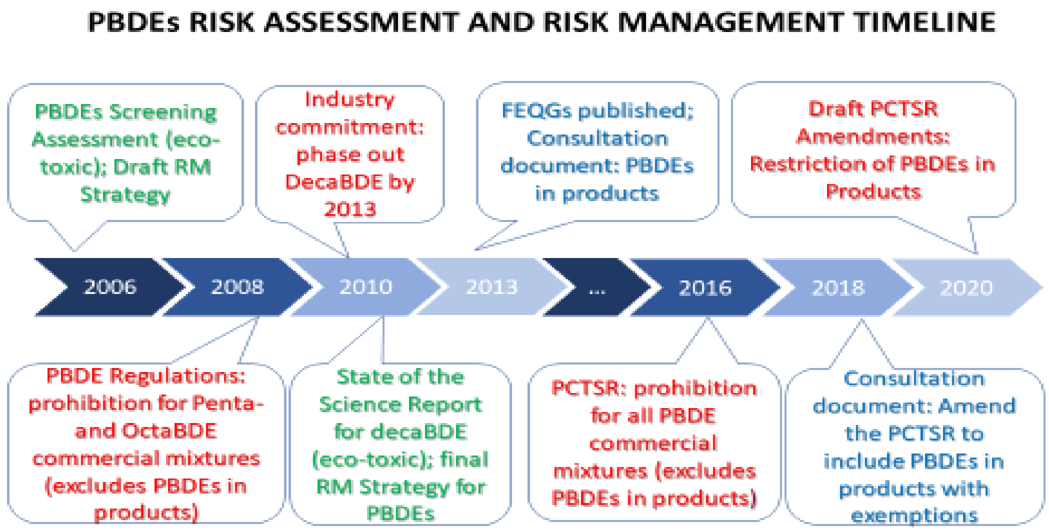

Figure 8. Timeline of actions taken towards managing risks for PBDEs.

Long description for the visually impaired:

This figure represents a timeline of actions taken towards assessing and managing the risks of PBDEs. The timeline lists the following:

- 2006: publication of the screening assessment for PBDEs indicating they are toxic to the environment and of the draft risk management strategy for PBDEs;
- 2008: publication of the PBDE Regulations, which prohibits the PentaBDE and OctaBDE commercial mixtures (excluding PBDEs in products);
- 2010: commitment announced by industry to phase out the DecaBDE commercial mixture by 2013
- 2010: publication of the State of the Science Report for decaBDE which concludes that decaBDE poses a higher risk to the environment than previously thought and publication of a revised Risk Management Strategy for PBDEs;
- 2013: publication of the Federal Environmental Quality Guidelines and the first of two consultation documents, focusing on PBDEs in finished products;
- 2016: publication of amendments under the *Prohibition of Certain Toxic Substances Regulations* (PCTSR) to prohibit all PBDE commercial mixtures, but excludes PBDEs in finished products;
- 2018: publication of a second consultation document to amend the PCTSR to prohibit PBDEs in products, with time-limited exemptions; and
- 2020: the expected publication of draft amendments under the PCTSR, focusing on prohibiting PBDES in products, with time-limited exemptions.

5 International Approaches

Currently, the majority of PBDEs come into Canada from imported products. For this reason, Canada must work collaboratively with other countries to reduce global use of PBDEs and minimize the cross-border movement of PBDEs into Canada, where possible. The following section discusses international commitments to help reduce entry of PBDEs into Canada.

5.1 Great Lakes Water Quality Agreement

Canada and the United States first signed the Great Lakes Water Quality Agreement in 1972. It was amended most recently in 2012 to enhance water quality programs that ensure the Great Lakes' "chemical, physical, and biological integrity". Annex 3 of the 2012 Agreement, "Chemicals of Mutual Concern" seeks to reduce releases of key chemicals, including PBDEs, into the air, water, land, sediment, and wildlife found in the Great Lakes basin ecosystem. Under Annex 3, Canada and the United States agreed to designate Chemicals of Mutual Concern (CMCs) in consultation with stakeholders and the public, and to prepare binational strategies to tackle risk management concerns in the Great Lakes. PBDEs were designated as a CMC in 2014.

The Governments of Canada and the United States have now prepared the Great Lakes Binational Strategy for Polybrominated Diphenyl Ethers (PBDEs) Risk Management to reduce PBDEs in the Great Lakes Basin (Environment and Climate Change Canada and the United States Environmental Protection Agency, 2019). Under this strategy, Canada has identified actions to reduce threats to the Great Lakes by reducing PBDEs. These include amending the PCTSR, enhancing compliance promotion and enforcement of existing actions, increasing public education on PBDEs, and enhancing monitoring of different sites in the Great Lakes.

5.2 Convention on Long-Range Transboundary Air Pollution and its Protocol on Persistent Organic Pollutants

Canada is a Party to the *Protocol on Persistent Organic Pollutants* (POPs; the Protocol) under the *Convention on Long-Range Transboundary Air Pollution*. This was the first international treaty to eliminate or reduce POPs. The Protocol on POPs is a precursor to the work being done under the *Stockholm Convention on Persistent Organic Pollutants*. The Protocol targets persistent organic pollutants, and included pentaBDE and octaBDE in its listing in 2009. Canada complies with all its requirements under the Protocol.

5.3 Stockholm Convention on Persistent Organic Pollutants

Canada and 182 other countries are Parties to the Stockholm Convention on Persistent Organic Pollutants (Stockholm Convention). This international treaty came into force in 2004. The treaty aims to protect human health and the environment from POPs, such as PBDEs. All PBDEs listed for elimination under the Stockholm Convention have time-limited exemptions to allow for the phase out of the use of these substances. In 2009, tetraBDE, pentaBDE, hexaBDE, and heptaBDE were listed to the Convention for elimination and decaBDE was listed to the Convention in 2017.

In 2017, the Parties completed an evaluation of the effectiveness of the Stockholm Convention in protecting human health and the environment from emissions and releases of persistent organic pollutants, which included tetraBDE, pentaBDE, hexaBDE, and heptaBDE. Environmental monitoring results were used as one indicator of the treaty's effectiveness.

This evaluation concluded that there was limited information available on the progress in eliminating PBDEs. The main challenges that were identified included information gaps related to the presence of PBDEs throughout their life cycle, from their presence in finished products to the disposal of those products. The evaluation also noted that air concentrations increased in the 1990s but started decreasing in the 2000s.

Canada continues to provide valuable scientific data to the Conference of Parties of the Stockholm Convention to evaluate the effectiveness of the treaty. A follow-up evaluation is underway and is expected to be completed in 2021.

6 Conclusions

The evaluation of the risk management for PBDEs highlights the approach taken over the last twelve years to meet the risk management and environmental objectives outlined in the Strategy. Key conclusions of this evaluation are as follows:

1. **Steady progress is being made towards preventing the manufacture, import, and use of PBDEs in Canada, and in minimizing releases through domestic actions. However, more time is required to determine the impact of recent and future amendments to the PCTSR.**
   - The domestic use and sale of all three PBDE commercial mixtures have ceased, demonstrating that Canadian industries and businesses have met the legal requirements and commitments under the PBDE Regulations and the more recent PCTSR, amended in 2016.
   - The proposed amendments under the PCTSR to restrict the import, manufacture, use, and sale of products containing PBDEs in Canada (including products made from recyclable materials containing PBDEs) would further reduce PBDE releases to the environment.
   - Although PBDEs are persistent in air, sediment, and wildlife, the environmental monitoring data has shown decreases in levels of PBDEs in air, sediment, and fish. However, levels of pentaBDE and decaBDE were above their FEQG levels in some sites and environmental media, such as bird eggs. Because there is continued global use of PBDEs, particularly in products, it will take years to observe further decreases in the environment.

2. **Canada's continued cooperation and leadership in national and international initiatives on PBDEs is required as PBDEs still enter Canada through imports of finished products and through long-range transport.**
   - National actions under the *Great Lakes Water Quality Agreement* are to reduce CMCs, such as PBDEs in the Great Lakes Basin. These actions include enhanced public education, environmental monitoring, continued risk management and compliance promotion/enforcement.

- Global efforts to eliminate PBDEs, such as those under the *Stockholm Convention on Persistent Organic Pollutants*, require Parties to implement risk management actions to reduce or minimize releases of POPs or to eliminate certain POPs completely. TetraBDE, pentaBDE, hexaBDE, heptaBDE, and decaBDE have been listed for elimination with time-limited exemptions, meaning that they must be phased out. Canada complies with the obligations under this treaty and works with other countries in advancing efforts under the Convention.
- A national Whales Initiative is underway to protect and support recovery of three endangered species of whales. One important part of the initiative focuses on conducting environmental monitoring and research to understand and quantify the contributions of various sources of land-based pollutants, such as PBDEs.

3. The upcoming PCTSR amendments will reduce releases of PBDEs from products and recycled materials to help meet the objectives of the Strategy.

- New amendments under the PCTSR would restrict PBDE concentrations in products, including prohibiting the manufacture of products from recyclable materials that contain PBDEs. This will address the risks from the use and disposal of products containing PBDEs and from the recycling sector. Performance measurement will continue to be an essential tool for compiling and analyzing information on the effectiveness in managing the risks of PBDEs.

7 Moving Forward

This report recommends that Environment and Climate Change Canada focus its efforts on four main areas: environmental monitoring of PBDEs; managing risks associated with PBDEs; communicating with the public; and engaging nationally and internationally.

Data collected from Environment and Climate Change Canada's environmental monitoring and surveillance program continues to provide information needed to assess the effectiveness of risk management for PBDEs. In partnership with various regional and international programs, both environmental monitoring data for air, sediment and biota on a periodic basis and monitoring of landfill leachate would be useful for measuring levels of PBDEs from products that enter landfills, and thereby, their potential release to the environment.

Domestic efforts to manage the risks associated with PBDEs are ongoing. Proposed amendments to the PCTSR are included in these efforts. Environment and Climate Change Canada will continue to measure the performance of these Regulations and other initiatives in protecting Canada's environment.

Environment and Climate Change Canada plays a role in informing Canadians about environmental risks from PBDEs and updates on risk management actions. This allows Canadians to make educated choices related to using products that contain PBDEs and their disposal or recycling.

Lastly, the Government of Canada will continue to support national and international action on PBDEs through continued engagement and leadership under the Stockholm Convention, the *Great Lakes Water Quality Agreement* and the Government of Canada Whales Initiative.

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9 Appendix: Three Commercial Mixtures of PBDEs in Canada and the World

Globally, there are three commercial mixtures of PBDEs that have been used as a flame retardant to add to products. Table 3 summarizes the percentages of each of the PBDEs in each commercial mixture.

Table 3. Composition of the three Global Commercial Mixtures of PBDEs. For the purpose of this document, PBDE commercial mixtures are capitalized to distinguish from the congeners they contain (i.e., "PentaBDE" vs. "pentaBDE").

Commercial Mixtures	PBDE Homologues						
	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%