Nomination of Polybrominated Diphenyl Ethers (PBDEs) as a Chemical of Mutual Concern under Annex 3 of the Great Lakes Water Quality Agreement

Chemical Background

- Polybrominated diphenyl ethers (PBDEs) are a class of substances used as flame retardants in a wide variety of products to prevent or slow ignition and burning (Environment and Climate Change Canada [ECCC], 2016; Agency for Toxic Substances and Disease Registry [ATSDR], 2017a).
- PBDEs are mixtures of several brominated hydrocarbons (or congeners), in which 2 to 10 bromine atoms are attached to the diphenyl ether molecule (**Figure 1**).

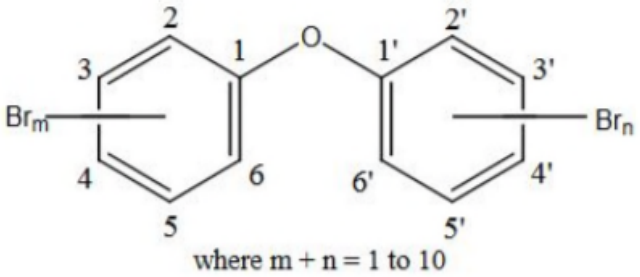

Figure 1: General chemical structure of PBDEs (ATSDR, 2017a).

- This structure can theoretically produce 209 possible unique congeners of PBDEs; however, only a subset of these exists in commercial PBDE mixtures.
- PBDEs are categorized by the degree of bromination, and their "homolog" refers to all congeners of PBDEs with the same number of bromines.
- Main uses of the three commercial mixtures in Canada and the U.S. include:
    - DecaBDE: electronic enclosures (e.g. television cabinets)
    - OctaBDE: plastics for business equipment
    - PentaBDE: foam for cushioning in upholstery (EC, 2006).
- DecaBDE commercial mixture is primarily used in polystyrene, particularly high impact polystyrene (HIPS) and to a lesser extent in resins.
    - 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 (EC, 2006).
- PBDEs have low vapour pressures, very low water solubility, and high octanol/water partition coefficient values; therefore, when these substances are released to water, they typically bind to the organic fraction of particulate matter, soils and sediment. Only a very small portion would remain in the water column (EC, 2006). Lower brominated PBDEs (tetra- to heptaBDEs) are slightly more soluble in water and have a greater propensity for volatilization and atmospheric transport; therefore, they tend to sorb to particulates in the atmosphere (EC, 2006).

- Higher brominated PBDEs have higher octanol-water (Log K_{ow}) and air-water (Log K_{aw}) partition coefficients and a greater propensity to remain in solid form; therefore, transport would likely be in the form of particles (EC, 2006).
- The lipophilic (dissolves in fats) and hydrophobic (repel water) properties of PBDEs make them more likely to bioaccumulate in terrestrial and aquatic food webs (EC, 2006).

Existing Scientific Data

1. TOXIC: Is the chemical substance toxic, persistent, and/or bioaccumulative?

Canada

- Ecological and human health screening assessments were conducted by Environment Canada (EC) and Health Canada (HC) under CEPA for seven PBDE congener groups on the Canadian Domestic Substances List (DSL; tetra-, penta-, hexa-, hepta-, octa-, nona-, and decaBDEs), which are contained in three commercial PBDE mixtures.
- The Ecological Screening Assessment report concluded that PBDEs are entering the environment in a quantity or concentration that have or may have an immediate or long-term harmful effect on the environment or its biodiversity (EC, 2006), and were added to the List of Toxic Substances in Schedule 1 of CEPA (Government of Canada, 2006).
- The Ecological Screening Assessment also concluded that:
    - Tetra-, penta-, and hexaBDE congeners meet the criteria for persistence and bioaccumulation, as defined by the *Persistence and Bioaccumulation Regulations* under CEPA, and their presence in the environment results primarily from human activity (EC, 2006). These three congeners meet the criteria set out in subsection 77(3) of CEPA for mandatory addition to the Virtual Elimination List (EC, 2010a).
    - The seven PBDEs (tetra- to decaBDE) that are found in commercial products met the criteria for persistence, as defined by the *Persistence and Bioaccumulation Regulations* (EC, 2010a). All seven PBDE groups are highly persistent and are subject to long-range environmental transport (EC, 2006).
- The Ecological State of the Science Report on decaBDE concluded that decaBDE may accumulate in organisms, and may transform into lesser-brominated PBDEs, potentially those that are bioaccumulative (EC, 2010b).
- HC's Screening Health Assessment on PBDEs noted that critical effects of the three commercial PBDE mixtures occur on the liver and neurobehavioural development, such as changes in movement and behaviour (HC, 2006).
- The report identifies critical health effects and lowest-observed-effect level (LOEL) for endpoints (developmental behavioural, liver, etc.) in various PBDE congeners and commercial mixtures (HC, 2006).
- In laboratory animals, decaBDE affects early fetal/neonatal development, the liver, the thyroid and potentially the endocrine system. The available studies suggest that decaBDE does not have significant genotoxic potential, and there is limited evidence for carcinogenicity in experimental animals (HC, 2012).

- PBDEs are not one of the five Persistent Bioaccumulative Toxic (PBT) chemical compound categories, or on the list of 16 PBT chemicals that are subject to Toxics Release Inventory (TRI)

reporting under Section 313 of the Emergency Planning and Community Right-to-Know Act (EPCRA; Toxics Release Inventory [TRI], 2017; U.S. EPA, 2017a); however, decaBDE is a PBT chemical and the TRI has been reporting its releases since 1988 (U.S. EPA, 2017b).

- The U.S. EPA is concerned that some of the component PBDE congeners are persistent, bioaccumulative, and toxic, and stated in their PBDE Action Plan that they intend to initiate actions to limit the exposure and release of PBDE congeners (U.S. Environmental Protection Agency [EPA], 2009).
- The U.S. Department of Health and Human Services Toxicological Profile for PBDEs identified that PBDEs are persistent in the environment (ATSDR, 2017a).
- The U.S. Department of Health and Human Services Toxicological Profile for PBDEs also identified that most congeners can be considered bioaccumulative, and that lower brominated congeners of PBDE tend to bioaccumulate more than higher brominated congeners (ATSDR, 2017; U.S. EPA, 2017c).
- The EPCRA has identified decaBDE as a toxic chemical and monoBDE as hazardous waste (ATSDR, 2017a).
    - MonoBDE is on the Resource Conservation and Recovery Act (RCRA) waste minimization persistent, bioaccumulative, and toxic (PBT) priority chemical list and the groundwater monitoring list (ATSDR, 2017a).
- The EPA assigns carcinogen risk Group D (*not classifiable as to human carcinogenicity*) to mono-, di-, tri-, tetra-, penta-, hexa-, octa-, and nonaBDEs; however, decaBDE is classified as Group C (*suggestive evidence of carcinogenic potential*; U.S. EPA, 2005; ATSDR, 2017b).
- Laboratory studies suggest that potential health risks of PBDEs including liver toxicity, thyroid toxicity, developmental and reproductive toxicity, and developmental neurotoxicity, and decaBDE has been found to have suggestive evidence of carcinogenic potential based on the U.S. EPA's Guidelines for Carcinogen Risk Assessment (U.S. EPA, 2010).

Other Jurisdictions

- The International Agency for Research on Cancer (IARC) has classified PBDE as a Group 3 carcinogen (*not classifiable as to its carcinogenicity to humans*) based on inadequate evidence of carcinogenicity in humans and inadequate or limited evidence in experimental animals (International Agency for Research on Cancer [IARC], 2020).

2. RELEASE: To what extent is the chemical substance released in the Great Lakes Basin?

- The primary Canadian and U.S. sources of PBDEs to the Great Lakes basin are anthropogenic and enter water or air through:
    - release from the manufacture, processing, and use of PBDEs and PBDE-containing products; and
    - release from incineration, recycling, and/or disposal of PBDE-containing products (e.g. landfill leachate discharges to surface water, volatilization from shredding of products for recycling).

- The Great Lakes are also exposed to global sources via long-range transport of PBDEs, with lower brominated PBDEs having the greatest potential for atmospheric transport (Gouin and Mackay, 2002; Wania and Dugani, 2003; EC, 2006).
- PBDEs have never been manufactured in Canada, but were imported as three commercial mixtures and have been used as additive flame retardants in a wide variety of products since the 1970's (e.g. plastics, computer housings, household appliances, furniture, upholstery, textiles, automotive/aircraft seating, electrical and electronic components, and other household products; EC, 2006). Two of the three commercial mixtures, known as PentaBDE and OctaBDE were phased out in 2004 and the third commercial mixture, DecaBDE was phased out in 2013, within Canada.
- In the U.S., production and import of PBDEs began in the late 1970s, and it is estimated that between 40,000 and 67,000 metric tons of PBDEs were produced worldwide between 1999 and 2002 (U.S. EPA, 2010).
- All U.S. domestic producers voluntarily ceased production by 2013; however, PBDEs may still be manufactured in small amounts (U.S. EPA, 2013).
- Despite restrictions on the manufacture and import of PBDEs, PDBE-containing products in use, transport, storage, and disposal phases may remain in service.
- 15,000 – 80,000 metric tons of total PBDEs were estimated to be in circulation in the Great Lakes basin in 2004 (**Table 1**; Abbasi et al., 2014).
    - Approximately 40% of the PBDEs being used in the Great Lakes basin in the peak usage year (2004) will still be in use in 2020.

Table 1: Estimated quantities of PBDEs in use in the Great Lakes basin.

PBDE Homolog	Range (metric tons)	Year	Where found, % of total PBDE use	% Expected to enter waste phase/remain in use by 2020
PentaBDE	2,000 – 10,000	2004	Furniture foams (60-65%) Vehicle foams (30-35%) EEE (2-3%)	All to leave the use phase
OctaBDE	500 – 2,000	2004	EEE (90%) Automotive sector (10%)	90% to leave the use phase
DecaBDE	10,000 – 70,000	2013	Automotive sector (25%) Textile (25%) Construction materials (25%) EEE (15%)	50% remain in use (of 2008 peak inventory)
Total PBDEs	15,000 – 80,000	2004		40% of the peak value (mainly decaBDE) remain in use

- The U.S. Toxics Release Inventory (TRI) program has been tracking reported releases of decaBDE to air, surface water, landfills and surface impoundments from industrial facilities since 1998 (TRI, 2017; **Figure 2**).
- Total releases from U.S. industry have decreased since 1998 due to regulations and bans on manufacturing, but PBDES are still being released to the environment.
    - Releases from landfills and surface impoundments increased from 2014 to 2016 by approximately 200,000 pounds.
- Canada's National Pollutant Release Inventory (NPRI) requires certain facilities report releases, disposals, and transfers for recycling of decaBDE (previously imported into Canada).

- In recent years, decaBDE emissions have declined in response to the phase out of imports of the DecaBDE commercial mixture, in addition to Canadian regulatory controls and the phase-out of decaBDE manufacturing that occurred in the U.S.

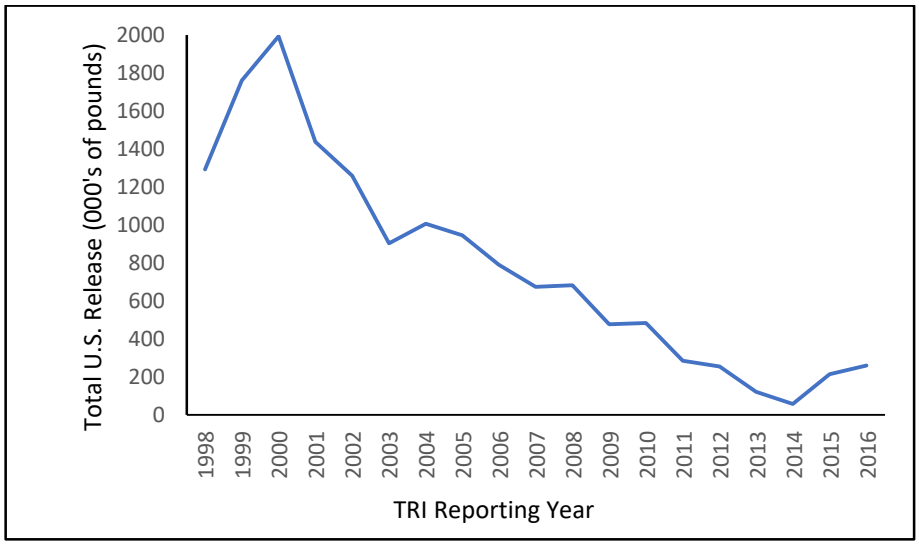

Figure 2: Total releases of DecaBDE from all sources to the environment from 1998-2016 (TRI, 2017).

- Despite restrictions on the manufacture and import of PBDEs in Canada and the U.S., it is expected that various PBDE congeners may be present in the environment either due to their release prior to phase-out, or due to items produced before phase-out remaining in use (EC, 2013).
- PDBE-containing products remain in use, transport, storage, and disposal phases remain in service and may continue to contribute to PBDE releases in the Great Lakes basin.

3. LEVELS: Are levels of the chemical substance harmful, or likely to become harmful, in the Great Lakes environment?

Environmental Quality Guidelines

- In Canada, Federal Environmental Quality Guidelines (FEQGs) have been developed for certain congeners of PBDEs in water, fish tissue, sediment, wildlife, and bird eggs to assess the ecological significance of levels of PBDEs in the environment and to protect all forms of aquatic life (EC, 2013; **Table 2**).
- The U.S. EPA and ATSDR have standards and recommendations for PBDEs in workplace air and oral and inhalation exposure (U.S. EPA, 2008; U.S. EPA, 2014; ATSDR, 2017a); however, no environmental quality guidelines exist.

Table 2: Canadian Federal Environmental Quality Guidelines (FEQGs) for PBDEs.

Homologue	Congener	Water (ng/L)	Fish Tissue (ng/g ww)	Sediment (ng/g dw)	Wildlife Diet (ng/g ww food soruce)	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	--

Sediment

- There are moderate exceedances of FEQGs in Lake Ontario sediment, where average pentaBDE concentrations were approximately twice the FEQG of 0.4 ng/g dw. In some locations, pentaBDE concentrations were 10-60 times greater than the FEQG (EC, 2011).
- DecaBDE exceeded the FEQG of 19 ng/g dw in Toronto Harbour and in six other locations in Lake Ontario (EC, 2011).
- More recently, ECCC analyzed six congeners of PBDEs (tri-, tetra-, penta-, hexa-, octa-, deca-) in sediments across Canada in 2009-2010 and 2013-2014, and found that the Great Lakes drainage area had pentaBDE concentrations above the FEQG of 0.4 ng/g dw, while the other congeners measured below guidelines (ECCC, 2020).
- A rapid increase in the accumulation of decaBDE in Lake Ontario sediment was observed between the mid-1980s and the early 2000s, followed by a decline. Other homologues decreased during that period. This may be explained by the increased use of the decaBDE commercial mixture in the 1990s and 2000s and the known high tendency of DecaBDE to bind to sediment and low tendency to degrade within sediment (**Figure 3**; EC, 2011).
- Tetra- and pentaBDE had the highest concentrations in sediment in the beginning of the period, but by the late 1980s, levels of decaBDE had surpassed levels of the other congeners, and remained dominant for the rest of the period (**Figure 3**; EC, 2011).
- DecaBDE concentrations in sediment of the Great Lakes region declined between 2009-2010 and 2013-2014 (ECCC, 2020).
- Sediment profiles in Lake Ontario indicates a leveling off of accumulation in the past decade, while other studies have shown total PBDE (especially deca-substituted BDE 209) are continuing to increase across all five Great Lakes, with doubling times ranging from 4 years to 74 years (ECCC and U.S. EPA, 2017).

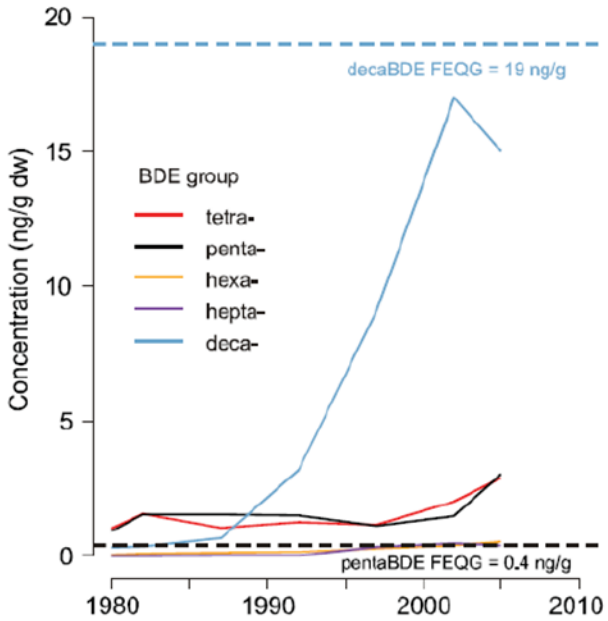

Figure 3: Average concentrations of PBDEs in Lake Ontario sediments from 1980 to 2009 (EC, 2011).

Fish

- Concentrations of pentaBDE reported for Lake Trout and Walleye in 2009 from all the Great Lakes are well above the FEQG of 1.0 ng/g ww. Some reported concentrations of tetraBDE were above the FEQG of 88 ng/g ww (EC, 2011). In 2012, concentrations of pentaBDE in Lake Trout were still above the FEQG (1.0 ng/g ww) in Lake Ontario (ECCC, 2017).
- The FEQG for pentaBDE (1.0 ng/g ww) was exceeded in 70% of fish examined in a study of Canadian fish, with the greatest exceedances in the Great Lakes (Gewurtz et al., 2011).
- Results from routine Canadian (1997 – 2009) and U.S. (1980 – 2000) federal monitoring of PBDEs in whole top predator fish from the Great Lakes indicated that concentrations of PBDEs in Lake Trout and Walleye rose continuously up to the early 2000s, and then began to decline, showing significant results for tetra-, penta-, and hexaBDE in Lake Ontario and Lake Michigan. Concentrations also declined in lakes Superior, Huron, and Erie; however, regressions are not significant (**Figure 4**; EC, 2011; ECCC and U.S. EPA, 2017).
- HexaBDE showed a stabilization trend and a decrease beginning around 1995 (**Figure 4**). The heavier homologues (hepta - through decaBDE) are not found in fish in substantial quantities due to their lower bioaccumulation potential. Levels of pentaBDE in fish tissue were 20–30-fold higher than the FEQG, but did not exceed the margin of safety built into the FEQG (88 ng/g; EC, 2011).

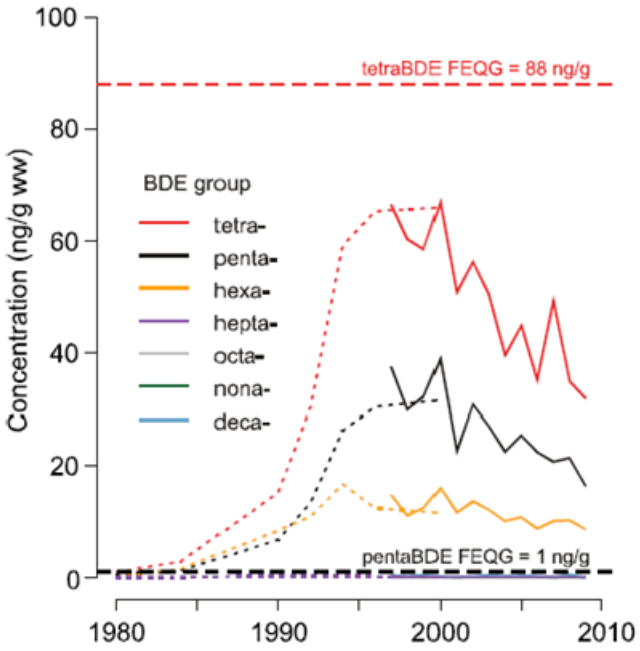

Figure 4: Average concentrations of PBDEs in Lake Ontario Lake Trout from 1980 to 2009 (EC, 2011).

Herring Gulls

- Maximum average values of pentaBDE in herring gull eggs from monitored colonies across the Great Lakes (1980-2010) were up to 20 times higher than the FEQG of 29 ng/g ww (**Figure 5**; EC, 2011).
- Concentrations of tetra-, penta-, and hexaBDE follow similar trends to fish; however, the peak years and decline occur several years later. In addition, decaBDE concentration, although relatively low, increased over the entire period from 1980-2010 (EC, 2011), and had higher concentrations in egg pools from 2012 compared to 2006 (**Figure 5**; Su et al. 2015).

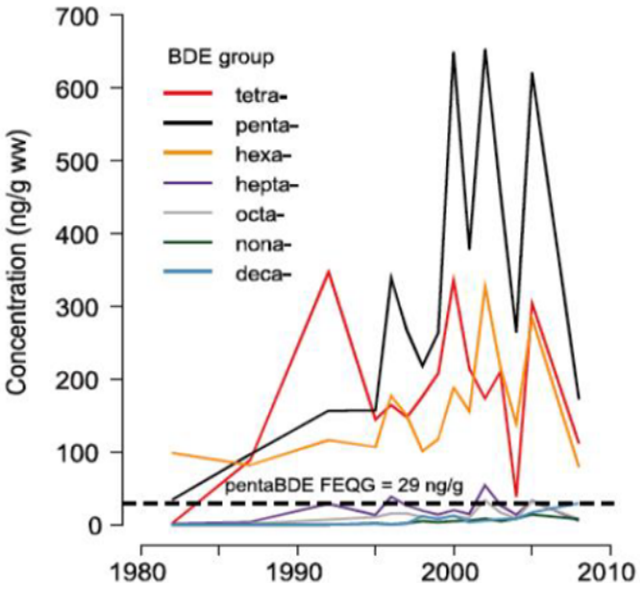

Figure 5: Average concentrations of PBDEs in herring gull eggs from Toronto Harbour from 1982 to 2008 (EC, 2011).

Air

- Increasing trends in PBDEs in air in northern Canada are indicative of long-range transport of PBDEs. At the same time, declines in tetra- and decaBDEs have been evident in southern Ontario (EC, 2010a).
- PBDE concentrations have decreased in air and precipitation samples at five sites near the North American Great Lakes from 2005 to 2011, which is correlated with the phase-out of penta- and octaBDE (IJC, 2016).
- Atmospheric concentrations show a generally decreasing trend over time at urban sites (e.g. Chicago, Cleveland) and at Lake Ontario and Lake Huron sites, but are generally unchanging at remote sites (e.g. Sleeping Bear Dunes, Eagle Harbor; Liu et al., 2016).
- Data collected by ECCC also show that PBDEs appear in higher concentrations near urban centers (e.g. 157 pg/m^3 detected in Hamilton, Ontario), and at lower concentrations in remote location (e.g. 7 pg/m^3 detected in Alert, Nunavut; EC, 2011).

Surface Water

- There is very minimal information on the concentrations of PBDEs in Great Lakes surface water.
- Surface water concentrations are higher in the lower Great Lakes, exhibiting spatial patterns consistent with consumer products as a primary source (ECCC and U.S. EPA, 2017).

4. ROUTE OF EXPOSURE: Are the Great Lakes a significant route of exposure to humans or wildlife for this chemical substance?

Exposure via Great Lakes Water and Sediments

- The atmosphere is the primary transport medium for PBDEs, and soils and sediments are environmental sinks (EC, 2010a; IJC, 2015).
- In Canada, manufacturing of consumer products is the greatest contributor of decaBDE to the atmosphere, and concentrations of decaBDE are higher in localized areas (where products are manufactured, or where electronics are recycled); however, the overall exposure of the general Canadian population to decaBDE from ambient air is considered to be low (Health Canada [HC], 2012).
- PBDEs enter a water body from atmospheric deposition, air-to-water transfer, or direct discharge from industries and wastewater treatment plants.
- The Great Lakes received approximately 0.17 tons of $\sum_9$BDEs and 4.4 tons of decaBDE in 2002, primarily from atmospheric deposition (Li et al., 2006). Additionally, the sedimentary record of PBDEs in Lake Ontario suggest that atmospheric deposition as the primary transport mechanism to the lake (Qiu et al., 2007).
- Once in the aquatic system, PBDEs partition between the water column and sediments in proportion to their physical-chemical properties (U.S. EPA, 2010).
- PBDEs have low water solubility and do not readily dissolve in surface water; therefore, the concentration of PBDEs in surface water remains low, and is likely not a route of exposure to humans or wildlife (U.S. EPA, 2010).
- Additionally, PBDEs have high log octanol water partition coefficients, which suggest a high absorption capacity for organic carbon in soils and sediments; therefore, benthic sediments are a primary sink for PBDEs, and may act as a route of exposure to aquatic organisms, which can then bioaccumulate up the aquatic food web beginning with benthic organisms and ending with predators at the top of the food chain (e.g., piscivorous fish, birds, and terrestrial mammals; U.S. EPA, 2010; IJC, 2015).
- A study of PBDEs in Great Lakes fish found that concentrations were highest in Common Carp and White Sucker. The results suggest that concentrations are higher in bottom dwellers compared to predator species (e.g. walleye, largemouth bass, yellow perch) due to their interactions with contaminated sediment at areas impacted by urbanization (Ghandi et al., 2017).
- This suggests that Great Lakes sediment are a route of exposure to Great Lakes fish.

Exposure via the Great Lakes Food Web

- PBDEs are lipophilic and hydrophobic compounds and readily bioaccumulate into terrestrial and aquatic food webs, which has resulted in accumulation of PBDEs in a wide variety of birds, fish, insects, and aquatic and terrestrial mammals in North America (U.S. EPA, 2010).
- Trophic level bioaccumulation of PBDEs in freshwater biota is similar to the pattern of bioaccumulation of other classes of lipophilic and persistent compounds such as the PCBs, i.e., the concentration of PBDEs from one trophic level to another seems to biomagnify between organisms (U.S. EPA, 2010).
- Across the Great Lakes, an analysis of 18 fish species between 2006 and 2013 found that decaBDE was the major congener in panfish, while tetraBDE was the major congener in top predators. Whole body and egg concentrations of PBDEs were greater than the corresponding fillets (Gandhi et al., 2017).

- The same study concluded that concentrations of PBDEs in fillets would result in consumption restrictions for the Common Carp form the Toronto waterfront area only, which is in proximity to the most urbanized region on the Canadian side of the basin (Gandhi et al., 2017).
- In general, PBDE concentrations in sport-fish fillets do not result in consumption advisories for the general or sensitive populations. However, fish consumption advisories exist across the Great Lakes due to concentrations of tetraBDE (BDE-47), which restrict consumption to 8-16 meals/month. Only common carp from the Toronto waterfront area would be considered restrictive (4 meals/month; Gandhi et al., 2017).
- The U.S. EPA's Great Lakes Human Health Fish Tissue Study (GLHHFTS) collected samples of fish commonly consumed by humans, and detected PBDEs in all 157 samples; however, less than 1% of the Great Lakes nearshore area sampled (or 4,282 square miles) exceeded the 210 ppb human health screening value for PBDEs (U.S. EPA, 2016).
- The evidence suggests that the Great Lakes food web could be a potential route of exposure of PBDEs to wildlife and humans through ingestion; however, at their current levels, PBDEs are not a major concern for consuming Great Lakes fish (Ghandi et al., 2017).

Other Routes of Exposure

Canada

- HC's *Human Health State of the Science Report on DecaBDE* includes an exposure assessment, which concluded that the predominant sources of exposure to PBDEs in Canada are breast milk for breast-fed infants, mouthing of hard plastic toys for children ages 0.5 to 4 years of age, and indoor dust and food for all other age groups (HC, 2012).
- The estimated total daily intake of decaBDE for various age groups in Canada is 0.0079 to 0.187 µg/kg-bw per day (HC, 2012).
- DecaBDE can be released from consumer products and become incorporated into indoor dust or adsorbed onto airborne particles, which may then be inhaled and/or ingested (HC, 2012).
- Data on levels of decaBDE in food are limited, but studies have shown low concentrations in meat, dairy products, fish, shellfish, eggs and oils; however, the contribution to food to the overall exposure of the general population in Canada to decaBDE is relatively low, and is similar to the contribution from the ingestion of indoor dust (HC, 2012).
- Children's toys manufactured in China, specifically hard plastic toys, were also recently identified as a potential source of exposure of young children to decaBDE. Exposure from mouthing hard plastic toys is estimated to be 1.2 × 10−4 mg/kg body weight (kg-bw) per day. This is twice the exposure estimate from soil (dust) for this age group (HC, 2012).

United States

- Human exposure to PBDEs may occur through ingestion of contaminated foods, dust or soil, breathing contaminated air, or having skin contact with contaminated soil, dust or commercial products (ATSDR, 2017a).
- In the U.S., the primary route of PBDE exposure to the general population (80-90% of total exposure) is through ingestion of contaminated dust in indoor environments and skin exposure

to dust (ATSDR, 2017a). Secondary exposure in the U.S (10-20%) of total exposure comes from ingestion of contaminated foods, including fatty fish and breast milk.
    - The estimated intake dose of total PBDEs is 7.1 ng/kg body weight/day for adults, 47.2 ng/kg body weight/day for children 1-5 years, 13.0 ng/kg body weight/day for children 6-11 years, and 8.3 ng/kg body weight/day for young adults 12-19 years (U.S. EPA, 2010).
- PBDEs can enter soil from discarded products (e.g., in landfills), and biosolids may also contain PBDEs and be inadvertently released to soils when applied to farm fields.
    - If you touch soil containing PBDEs, a small amount of PBDEs may pass through your skin into the bloodstream; ingestion of soil can lead to higher PBDE exposure. This route may be especially important for children (ATSDR, 2017a).
- Drinking water is not a major exposure route for PBDEs because the compounds bind so strongly to sediment and soil (ATSDR, 2017a).

5. SCALE: Does the geographic scale of the levels of the chemical substance in the Great Lakes have binational significance?

- Despite binational efforts to reduce PBDE releases, they still enter the environment from in-use products and have been detected in environmental media across the Great Lakes basin in both Canada and the U.S.
- Compared to other drainage regions in Canada, the Great Lakes had a higher proportion of fish samples exceed FEQGs for tetra- and pentaBDE between 2013 and 2015 (ECCC, 2020).
    - Only the Great Lakes region had concentrations above the guidelines for tetraBDE, and all samples exceeded guidelines for pentaBDE.
- Additionally, only the Great Lakes drainage basin had sediment exceedance for all three sampled homologs (tetra- penta- and decaBDE) sampled between 2007 and 2018 (ECCC, 2020).
- Atmospheric monitoring data have indicated higher concentrations of PBDEs in urban centers. Given the concentrated population density and industrial activity on both sides of the Great Lakes basin, PBDE levels may have a binational impact.

6. MANAGEMENT: To what extent are the uses and releases of the chemical substance controlled/managed?

Federal Actions

Canada

Regulations & Risk Management Actions

- In 2008, the *Polybrominated Diphenyl Ethers Regulations* (SOR/2008-218) prohibited the manufacture of tetra-, penta-, hexa-, hepta-, octa-, nona-, and decaBDE in Canada. They also prohibited to the use, sale, offer for sale, and import of tetra-, penta-, and hexaBDE and mixtures, polymers and resins containing them.
- This regulation was repealed when the *Regulations Amending the Prohibition of Certain Toxic Substances Regulations, 2012* came into force in December 2016, which expanded the

prohibition to all PBDEs (including decaBDE) and products containing them, except manufactured items (ECCC, 2016).

Monitoring, Surveillance and Research

- ECCC conducts monitoring for PBDEs in air, fish, herring gull and European starling eggs, sediment, and water under several different initiatives, including the CMP.
- ECCC and the Ontario Ministry of Environment, Conservation and Parks (MECP) conduct in-depth assessment of surface waters, surface sediments, and sediment cores on a rotational basis from one Great Lake annually. The annual assessment incorporates a range of contaminants, including PBDEs at selected locations in selected media.
- Results are published in government reports, peer-reviewed articles, and Great Lakes basin data is available on the ECCC Open Government Portal.
- The NPRI tracks industrial releases, disposals, and transfers of decaBDE since 1993.
- The Canadian Environmental Sustainability Indicators (CESI) program provides data and information to track Canada's performance on key environmental sustainability issues. The PBDEs in Fish and Sediment indicators identify drainage regions where concentrations are within or have exceeded the FEQGs for PBDEs in fish and sediment.

United States

Regulations & Risk Management Actions

- Under the Toxic Substances Control Act (TSCA), mono-, penta-, octa-, and decaBDEs must be reported by manufacturers and importers at plant sites.
    - The TSCA was amended in 2016 by the Frank R. Lautenberg Chemical Safety Act, which included a requirement for the U.S. EPA to evaluate the risk of chemicals, including DecaBDE, for expediting action to reduce exposure.
- The U.S. EPA's SNUR (74 FR 34015) for PBDEs in 2006 required anyone who intended to manufacture or import a chemical mixture containing pentaBDE or octaBDE to notify the U.S. EPA at least 90 days in advance to allow the U.S. EPA to assess the intended use of the chemical or mixture to determine if it needs to be limited or prohibited.
    - In 2012, a proposal to amend the SNUR included the processing of any combination of the pentaBDE and octaBDE congeners, the manufacturing, import, or processing of decaBDE, and the manufacturing, importing or processing of any article to which PBDEs had been added.
    - A Toxic Substances Control Act (TSCA) section 4 test rule for penta-, octa-, and decaBDE was simultaneously proposed, which would require the development of information to determine the health and environmental effects of manufacturing, processing, or other activities involving these PBDE mixtures.
    - To date, neither rule has been finalized, and there is no explicit prohibition of decaBDE, other penta- or octaBDE congeners, or PBDE-containing products.

Pollution Prevention Actions

- Under the U.S. EPA's PBDEs Action Plan (2009), the *Alternatives Assessment for the Flame Retardant Decabromodiphenyl Ether* evaluated 29 potentially viable alternatives to decaBDE.

Monitoring, Surveillance and Research

- The U.S. EPA is mandated under the Clean Water Act to establish a Great Lakes system-wide surveillance network to monitor the water quality of the Great Lakes, with specific emphasis on the monitoring of toxic pollutants in Great Lakes media.
    - Long-term programs track trends of PBDEs to assess environmental health.

Provincial and State Actions

- As previously mentioned, as part of ongoing Great Lakes program activity both ECCC and MECP conduct monitoring and surveillance in the Great Lakes surface waters and sediments for PBDEs.
- Great Lakes States including Illinois, Michigan, Minnesota, and New York have established bans on the manufacturing, processing, or distribution of products or the flame-retardant part of a product containing more than 0.1% of penta- and octaBDE.
    - Michigan and Minnesota have some products exemptions.
    - As of July 1, 2019, Minnesota also banned certain products containing decaBDE exceeding 0.1%.
- Great Lakes States Pennsylvania, Ohio, and Wisconsin do not have state regulations for PBDEs; however, Pennsylvania and Wisconsin have mandatory electronics recycling laws and prohibitions on landfill or incineration disposal of electronics.

Binational Actions

- The U.S. Integrated Atmospheric Deposition Network (IADN) and Canada's Monitoring and Surveillance in the Great Lakes Basin (GLB) Program includes long-term atmospheric monitoring stations that have been in operation since 1990 as a joint effort to support the GLWQA, and are managed by U.S. EPA and ECCC, respectively.
    - The goal of these two programs is to determine the spatial and temporal trends of toxic chemicals in Great Lakes air, estimate atmospheric loadings of toxic chemicals to the Great Lakes, and identify sources and/or source regions.
    - Methods for PBDEs have been implemented since their addition to the list of routinely monitored analytes in 2005.
    - Data are publically available on U.S. and Canadian open data platforms.

International Actions

- The United Nations Environment Program (UNEP) Stockholm Convention on Persistent Organic Pollutants (POPs) listed tetra-, penta-, hexa-, and heptaBDE to Annex A with specific exemptions in 2009. DecaBDE was added in 2017.
    - A listing in Annex A aims to eliminate the production, use, import and export of the substance. Canada signed and ratified the Convention in 2001.
    - Canada ratified the listing of tetra-, penta-, hexa-, and heptaBDE in April 2011 and meets these obligations through the Prohibition of Certain Toxic Substances Regulations, 2012 (SOR/2012-285).

    - The U.S has signed the Convention but has yet to provide ratification, acceptance, approval, or accession; therefore, the Convention has not yet entered into force for the U.S.
- The Basel Convention on the Control of Transboundary Movements of Hazardous Wastes and Their Disposal is focused on the management of POPs when they become waste.
    - Under the Basel Convention, technical guidelines have been developed for the environmentally sound management of wastes consisting of, containing, or contaminated with PBDEs.
    - Canada signed and ratified the Basel Convention in 1992.
    - The U.S. signed the Convention in 1990, but has not yet ratified it.

Data Gaps and Further Action Required

Sources

- Limited understanding of PBDE manufacturers, processors, or users of PBDE-containing products exists in Canada and the U.S.
- Testing is required to determine the concentration of PBDEs in products that are being imported.
- There are no disclosure requirements for the PBDE content of finished products.

Risk Management Actions

- Regulations have not been established in Canada for import of manufactured items containing PBDEs.
- Additional compliance promotion campaigns are required to improve awareness and compliance.
- In the U.S., the SNUR does not include decaBDE, all congeners of penta- and octaBDE, or PBDE-containing products; therefore, continued PBDE use is not prohibited.
- PBDEs are not currently covered under the Clean Air Act or the Clean Water Act, and efforts should be made to evaluate the human health and environmental risk profile of PBDEs and determine whether additional coverage under other regulations would be useful.
- There is insufficient monitoring data to evaluate the performance of existing risk management activities.
- There are currently no environmental water quality, biota/diet, or sediment concentrations standards in effect in the U.S.
- There are no human health guidelines or fish consumption advisories.

Monitoring, Surveillance, and Research

- More monitoring of PBDEs in environmental media in the Great Lakes is required to better understand long-term trends, and long-range atmospheric transport and deposition.
- Further research on the effects of the degradation byproducts of PBDEs is required.
- Additional monitoring and modelling of PBDEs and the alternative brominated flame retardant products taking their place in environmental media is needed.
- Releases from products in use, as well as the extent to which PBDE can be released from the waste stream (landfill, incinerators) is unknown.

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