Format for submitting pursuant to Article 8 of the Stockholm Convention the information specified in Annex E of the Convention

Introductory information

Name of the submitting Party/observer

NGO Observer: Environmental Health Fund on behalf of the International POPs Elimination Network (IPEN)

Contact details

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Chemical name

Diphenyl ether, octabromo derivative (octabromodiphenyl ether, octaBDE)
CAS = 32536-52-0
Synonyms: octabromobiphenyl oxide, octabromodiphenyl oxide, octabromo phenoxybenzene and benzene, 1,1' oxybis-, octabromo derivative

Commercial products:

DE-79 (BDE153, BDE154, BDE196, BDE197, BDE203, BDE207) [1]

Bromkal 79-8DE (BDE183, BDE197, BDE207, BDE209, BDE203, BDE196, BDE208, BDE206, BDE204, BDE181, BDE191, BDE173/190, BDE205) [2]

Date of submission

8 February 2007

[1] La Guardia MJ, Hale RC, Harvey E. Bioaccumulation and debromination of polybrominated diphenyl ethers (PBDEs) Ander environmental conditions. Virginia Institute of Marine Science School of Marine Science, SETA, 2004 http://www.vims.edu/env/people/staff/La%20Guardia_SETAC_04.pdf)

[2] Korytar P, Covaci A, de Boer J, Gelbin A, Brinkman UA Th. Retention-time database of 126 polybrominated diphenyl ether congeners and two Bromkal technical mixtures on seven capillary gas chromatographic columns, Netherlands Institute for Fisheries Research, Animal Sciences Group, Wageningen UR, P.O. Box68, 1970 IJmuiden, The Netherlands; Department of Analytical Chemistry and Applied Spectroscopy, Free University of Amsterdam, de Boelelaan 1083,
1081 HV Amsterdam, The Netherlands; Toxicological Center, University of Antwerp, Universiteitsplein 1, 2610 Wilrijk, Belgium; AccuStandard, 125 Market St., New Haven, CT 06513, USA
http://www.accustandard.com/asi/pdfs/PBDE_retention_time.pdf

(a) Sources, including as appropriate (provide summary information and relevant references)

(i) Production data:

Quantity

In the USA, commercial pentaBDE, octaBDE, and decaBDE mixtures were each produced or imported at greater than 1,000,000 pounds (454 metric tons) per year in 1990, 1994, and 1998.
Hooper, K, McDonald TA. Hazardous Materials Laboratory, California Environmental Protection Agency, Berkeley, California, USA; and Office of Environmental Health Hazard Assessment, California Environmental Protection Agency, Oakland, California, USA. The PBDEs: An emerging environmental challenge and another reason for breast-milk monitoring programs. Environ Health Perspect 108:387-392, March 2000

"The global market demand in 1999 for Deca-, Octa-, and Penta-BDEs in 1999 was 54,800, 3825, and 8400 tonnes, respectively;
Alaee M, Arias P, Sjodin A, Bergman A. National Water Research Institute, 867 Lakeshore Road, PO Box 5050, Burlington, Ontario, Canada L7R 4A6. Mehran.alaee@ec.gc.ca An overview of commercially used brominated flame retardants, their applications, their use patterns in different countries/regions and possible modes of release. Environ Int. 2003 Sep;29(6):683-9.

Location

(ii) Uses

"Octa-BDE is produced in the lowest quantity and is mainly used in ABS resins."
Alaee M, Arias P, Sjodin A, Bergman A. National Water Research Institute, 867 Lakeshore Road, PO Box 5050, Burlington, Ontario, Canada L7R 4A6. Mehran.alaee@ec.gc.ca An overview of commercially used brominated flame retardants, their applications, their use patterns in different countries/regions and possible modes of release. Environ Int. 2003 Sep;29(6):683-9.

(iii) Releases

Discharges

"Polybrominated diphenyl ether (PBDE) concentrations were measured in surficial sediments from coastal sediments receiving industrial and municipal effluents in Kuwait. The summation PBDE concentrations varied by two orders of magnitude ranging from 80 to 3800 pg g(-1)dw. The congener distribution was dominated by BDE 183, with minor contributions from BDEs 154 and 153. The similarity between the congener profile to that of the technical octa formulation (Bromkal 79-8DE) suggests a source of this product in Kuwait. The observed gradient in concentration distribution, with high summation PBDE concentrations near the shore and an exponential decrease seaward, indicates that

wastewater discharge from industrial activities in the study area is the primary source of these compounds in the sediments."
Gevao B, Beg MU, Al-Ghadban AN, Al-Omair A, Helaleh M, Zafar J. Department of Environmental Science, Kuwait Institute for Scientific Research, P.O. Box 24885, 13109 Safat, Kuwait. bgevao@safat.kisr.edu.kw Spatial distribution of polybrominated diphenyl ethers in coastal marine sediments receiving industrial and municipal effluents in Kuwait.Chemosphere. 2006 Feb;62(7):1078-86. 2005 Jul 12.

This study examined PBDEs in the Pearl River Delta and South China Sea." The major sources of PBDEs were probably waste discharges from the cities of Guangzhou, Dongguan, and Shenzhen, the three fastest growing urban centers in the PRD."
"A total of 66 surface sediment samples were collected and analyzed to determine the concentrations of 10 PBDE congeners (BDE-28, -47, -66, -100, -99, -154, -153, -138, -183, and -209). The concentrations of BDE-209 and SigmaPBDEs (defined as the sum of all targeted PBDE congeners except for BDE-209) ranged from 0.4 to 7340 and from 0.04 to 94.7 ng/g, respectively. The SigmaPBDEs concentrations were mostly < 50 ng/g, within the range for riverine and coastal sediments around the world, whereas the BDE-209 concentrations at the most contaminated sites were at the high end of the worldwide figures. Congener compositions were dominated by BDE-209 (72.6 - 99.7%), with minor contributions from penta- and octa-BDEs. Slightly different PBDE compositions were observed among samples collected from different locations, attributable to possible decomposition of highly brominated congeners and/or redistribution between particles of various sizes during atmospheric or fluvial transportation. The PBDE patterns in the SCS and Pearl River Estuary sediments were similar to those in sediments of the Zhujiang and Dongjiang Rivers, reflecting the widespread influence from local inputs."
Mai B, Chen S, Luo X, Chen L, Yang Q, Sheng G, Peng P, Fu J, Zeng EY. State Key Laboratory of Organic Geochemistry, Guangzhou Institute of Geochemistry, Chinese Academy of Sciences, Guangzhou 510640, China. nancymai@gig.ac.cn Distribution of polybrominated diphenyl ethers in sediments of the Pearl River Delta and adjacent South China Sea. Environ Sci Technol. 2005 May 15;39(10):3521-7.

Losses

PBDEs and other flame retardants were measured in air samples collected in the US from near Lake Michigan to the Gulf of Mexico. "The mean sigmaPBDE atmospheric concentration was 100 +/- 35 pg/m3 at the Chicago site, which was 3-6 times higher than that at the other sites. The sigmaPBDE atmospheric concentrations at the Chicago site were significantly higher than previous measurements made in 1997-1999." "Higher BDEs (hepta- through deca-BDEs) were mostly detected in the particle phase. On the basis of the congener distributions in the samples, the concentrations were divided into three groups: penta-BDEs, octa-BDEs, and deca-BDEs. Penta-BDEs were the most concentrated at the Chicago site and the least concentrated at the Louisiana site; octa-BDE concentrations were low at all of the sites…"
Hoh E, Hites RA. School of Public and Environmental Affairs, Indiana University, Bloomington, Indiana 47405, USA. Brominated flame retardants in the atmosphere of the East-Central United States. Environ Sci Technol. 2005 Oct 15;39(20):7794-802.

Emissions

Brominated flame retardants including octaBDE were measured in a Swiss recycling plant in the fine dust fraction recovered in the off-gas purification system. The average concentration of octaBDE in small waste electrical equipment that was sampled in 2003 was 530 mg/kg. This amount agreed with data calculated using a substance flow analysis method for content of octaBDE in Switzerland in the 1990s. “The presence of BFRs, in particular PBDEs in the low grams per kilogram concentration range, in the fine dust fraction recovered in the off-gas purification system of the recycling plant reveals a high potential for BFR emissions from WEEE management and point out the importance for environmentally sound recycling and disposal technologies for BFR-containing residues.”
Morf LS, Tremp J, Gloor R, Huber Y, Stengele M, Zennegg M. Environmental Management, GEO Partner AG, Baumackerstrasse 24, 8050 Zurich, Switzerland. morf@geopartner.ch Brominated flame retardants in waste electrical and electronic equipment: substance flows in a recycling plant. Environ Sci Technol. 2005 Nov 15;39(22):8691-9.

This study found PBDEs in recycled aluminum smelter ashes. “Induction furnace ash contained tetra- to octa-BDEs about 2000ng g(-1) in similar congener ratios as the original scrap, but contents of nona- and deca-BDEs were only 25 and 5ng g(-1) indicating their significant degradation in ALS process.”
Sinkkonen S, Lahtipera M, Vattulainen A, Takhistov VV, Viktorovskii IV, Utsal VA, Paasivirta J. Department of Chemistry, University of Jyvaskyla, P.O. Box 35, FIN 40351 Jyvaskyla, Finland. Analyses of known and new types of polyhalogenated aromatic substances in oven ash from recycled aluminium production. Chemosphere. 2003 Jul;52(4):761-75.

(b) Hazard assessment for endpoints of concern, including consideration of toxicological interactions involving multiple chemicals **(provide summary information and relevant references)**

Neurological effects

This study examined developmental neurological effects after neonatal Naval Medical Research Institute male mice were exposed on postnatal day 3 or 10 to 21 mumol/kg body weight nonaBDE (PBDE206), octaBDE (PBDE203), or heptaBDE (PBDE183) (also part of the commercial octaBDE mixture). The mice were assessed in a spontaneous behavior test and the Morris water maze test at 2-3 months age. “PBDE 203 and PBDE 206, when administered on neonatal day 10, caused disturbances in spontaneous behavior, leading to disrupted habituation and a hyperactive condition in adults at the age of 2 months. These behavioral changes were also seen in 2-month-old mice exposed to PBDE 203 on neonatal day 3. Furthermore, exposure to PBDE 203 on neonatal day 10 affected learning and memory functions in adult mice. The developmental neurotoxic effects were most pronounced in mice exposed to PBDE 203. These developmental neurobehavioral defects were in agreement with those we observed previously with lower brominated PBDEs and with PBDE 209.”

Viberg H, Johansson N, Fredriksson A, Eriksson J, Marsh G, Eriksson P. Department of Environmental Toxicology, Uppsala University, Norbyvagen 18A, S-752 36 Uppsala, Sweden. Neonatal exposure to higher brominated diphenyl ethers, hepta-, octa-, or nonabromodiphenyl ether, impairs spontaneous behavior and learning and memory functions of adult mice. Toxicol Sci. 2006 Jul;92(1):211-8. 2006 Apr 12.

This study tested a commercial pentaBDE mixture (DE-71) and a commercial octaBDE mixture (DE-79) for their effects on intracellular signaling, critical for development and functioning of the nervous system. The commercial octaBDE mixture did not effect protein kinase C translocation (measured by phorbol ester binding in rat cerebellar granule cells) or calcium uptake by microsomes and mitochondria at concentrations up to 30 mug/ml.
Kodavanti PR, Ward TR. Cellular and Molecular Toxicology Branch, Neurotoxicology Division, NHEERL, ORD, U.S. Environmental Protection Agency, Research Triangle Park, North Carolina 27711, USA. kodavanti.prasada@epa.gov Differential effects of commercial polybrominated diphenyl ether and polychlorinated biphenyl mixtures on intracellular signaling in rat brain in vitro. Toxicol Sci. 2005 Jun;85(2):952-62. 2005 Mar 16.

This study examined neurotoxicity by measuring plasma membrane uptake of the neurotransmitters dopamine, glutamate and gamma-amino-n-butyric acid (GABA). OctaBDE and decaBDE did not affect uptake.
Mariussen E, Fonnum F. Division for Protection and Material, Norwegian Defence Research Establishment, P.O. Box 25, N-2027 Kjeller, Norway. The effect of brominated flame retardants on neurotransmitter uptake into rat brain synaptosomes and vesicles. Neurochem Int. 2003 Sep-Oct;43(4-5):533-42

An in vitro neuronal culture model was used to test the effects of a commercial pentaBDE mixture (DE-71) and a commercial octaBDE mixture (DE-79) on arachidonic acid (AA) release. The release of arachidonic acid through a phospholipase dependent mechanism has been associated with learning and memory. The commercial octaBDE mixture did not stimulate release of arachidonic acid at levels up to 50 microg/ml.
Kodavanti PR, Derr-Yellin EC. Cellular and Molecular Toxicology Branch, Neurotoxicology Division, MD 74B, NHEERL, ORD, U.S. Environmental Protection Agency, Research Triangle Park, North Carolina 27711, USA. kodavanti.prasada@epa.gov Differential effects of polybrominated diphenyl ethers and polychlorinated biphenyls on [3H]arachidonic acid release in rat cerebellar granule neurons. Toxicol Sci. 2002 Aug;68(2):451-7.

Immunotoxicity

This study examined immunomodulation in captive nestling American kestrels (Falco sparverius) after injecting eggs with PBDEs at 18.7 microg sigmaPBDEs/egg to approximate levels in Great Lakes birds. In addition, nestlings consumed 15.6+/-0.3 ng/g body weight per day of PBDEs which resulted in higher body burdens 86.1+/-29.1 ng/g ww vs. 0.73+/-0.5 ng/g ww. “PBDE-exposed birds had a greater PHA response (T-cell-mediated immunity), which was negatively associated with increasing BDE-47 concentrations, but a reduced antibody-mediated response that was positively associated

with increasing BDE-183 concentrations. There were also structural changes in the spleen (fewer germinal centers), bursa (reduced apoptosis) and thymus (increased macrophages), and negative associations between the spleen somatic index and sigmaPBDEs, and the bursa somatic index and BDE-47. Immunomodulation from PBDE exposure may be exacerbated in wild birds experiencing greater environmental stresses."
Fernie KJ, Mayne G, Shutt JL, Pekarik C, Grasman KA, Letcher RJ, Drouillard K. Canadian Wildlife Service, PO Box 5050, 867 Lakeshore Rd., Burlington, Ontario, Canada, L7R 4A6. kim.fernie@ec.gc.ca Evidence of immunomodulation in nestling American kestrels (Falco sparverius) exposed to environmentally relevant PBDEs. Environ Pollut. 2005 Dec;138(3):485-93

Fetal toxicity / teratogenicity

"The critical effects of PentaBDEs are those on neurobehavioural development (from 0.6 mg/kg body weight) and, at somewhat higher dose, thyroid hormone levels in rats and mice, of OctaBDEs on fetal toxicity/teratogenicity in rats and rabbits (from 2 mg/kg body weight),…"
Darnerud PO. Swedish National Food Administration, PO Box 622, Uppsala SE-751 26, Sweden. per.ola.darnerud@slv.se Toxic effects of brominated flame retardants in man and in wildlife. Environ Int. 2003 Sep;29(6):841-53

"In summary, developmental effects are observed in rats in two studies and they do not seem to be related to maternal toxicity (only decrease in maternal body weight gain during days 16-20 of gestation or decrease in body weight gain interrelated with resorptions and small fetal body weights). These developmental effects are not confirmed in a third assay in rats which was conducted with a test article containing a lesser percentage of octabrominateddiphenyl oxide component. In rabbits, the substance produces only slight foetotoxicity along with a decreased bodyweight gain of the dams at the highest dose. However it must be noticed that this decrease had already happened before the treatment. The lowest identified NOAEL is considered for the risk characterisation i.e. 2 mg/kg/day as obtained in the rabbit. Some of the above mentioned results are considered as borderline but since some of these results are indicative of developmental effects which are most likely unrelated to maternal toxicity, it was deemed cautious to apply a classification: Toxic for reproduction cat. 2 R61."
European Union Risk Assessment Report, Diphenyl ether, octabromo derivative, Risk Assessment, Final Report 2003, France and United Kingdom, 2003

Thyroid

"Following oral administration, thyroid gland effects are observed including increases in thyroid weight and histopathological changes suggesting an increase in thyroid gland stimulation. It should be noticed that no thyroid hormonal measurement was carried out in this study. In a recent study, especially designed to investigate thyroid hormone concentrations in weanling rats, oral exposure to a mixture of OBDPO 30.7% and HpBDPO 45.1% for 4 days, induced a dose dependent depletion of T_4 from 10 mg/kg/day as well as a decrease of serum T_3 from 100 mg/kg/day without effect on TSH level. In the recent inhalation studies, it was shown a thyroid hormonal disturbance with a decreased

T_4 level and an increased TSH level from 16 mg/m^3 without thyroid weight or histopathological changes up to 202 mg/m^3. Due to species differences in thyroid metabolism it is unlikely that the effects on thyroid status via an induction of the hepatic enzymes would occur in human. However mechanisms other than T4 glucuronidation may not be completely disregarded." "The changes in thyroid status are apparent within 4 and 13 weeks of repeated oral dosing at 1,000 ppm and above and within 13 weeks of repeated inhalation dosing from 16 mg/m^3 (analytical concentration)."
European Union Risk Assessment Report, Diphenyl ether, octabromo derivative, Risk Assessment, Final Report 2003, France and United Kingdom, 2003

Adrenal

This study used the H295R human adrenocortical carcinoma cell line to assess effects of PBDEs and other substances on the combined 17alpha-hydroxylase and 17,20-lyase activities of CYP17. "CYP17 enzyme catalyzes an important step in sex steroidogenesis and is responsible for the biosynthesis of dehydroepiandrosterone (DHEA) and androstenedione in the adrenals." "None of the parent/precursor BFRs had a significant effect ($P < 0.05$) on CYP17 activity except for BDE-183, which showed significant inhibition of CYP17 activity at the highest concentration tested (10 muM), with no signs of cytotoxicity as measured by mitochondrial toxicity tests (MTT)."
Canton RF, Sanderson JT, Nijmeijer S, Bergman A, Letcher RJ, van den Berg M. Institute for Risk Assessment Sciences (IRAS), University of Utrecht, Yalelaan 2, 3508 TD, Utrecht, The Netherlands. r.Fernandezcanton@iras.uu.nl In vitro effects of brominated flame retardants and metabolites on CYP17 catalytic activity: a novel mechanism of action? Toxicol Appl Pharmacol. 2006 Oct 15;216(2):274-81.

Enzyme and receptor effects

This study examined the ability of PBDEs to bind or activate the Ah receptor (AhR) in stably transfected rodent hepatoma cells lines with an AhR-EGFP reporter gene. The enzyme, 7-Ethoxyresorufin-O-deethylation (EROD) was used as a marker for CYP1A1 activity. "Dose- and bromination-specific inhibition of 2,3,7,8-tetrachlorodibenzo-p-dioxin (TCDD)-induced responses was measured by their ability to inhibit the induction of AhR-EGFP expression and EROD activity. Individual exposure to these PBDEs did not result in any increase in induction of AhR-EGFP or CYP1A1 activity. The lower brominated PBDEs showed the strongest inhibitory effect on TCDD-induced activities in both cell lines. While the highest brominated PBDE tested, BDE-183, inhibited EROD activity, it did not affect the induction of AhR-EGFP expression."
Peters AK, Nijmeijer S, Gradin K, Backlund M, Bergman A, Poellinger L, Denison MS, Van den Berg M. Institute for Risk Assessment Sciences, Utrecht University, PO Box 80176, Yalelaan 2, 3508 TD Utrecht, The Netherlands. l.peters@iras.uu.nl Interactions of polybrominated diphenyl ethers with the aryl hydrocarbon receptor pathway. Toxicol Sci. 2006 Jul;92(1):133-42. 2006 Apr 6

This study measured the binding affinity of PBDEs to the Ah receptor (AhR) in Sprague-Dawley rat hepatocytes to investigate the possible dioxin-like activity of the substances. "PBDE congeners 77 [tetra], 119 [penta], and 126 [penta] were moderately active towards DRE (dioxin response element) binding and induced responses of both CYP1A1

mRNA and CYP1A1 protein equivalent to the maximal response of TCDD (2,3,7,8-tetrachlorodibenzo-p-dioxin) in primary Sprague-Dawley rat hepatocytes, although at concentrations three to five orders of magnitude greater than TCDD. These congeners showed additive (throughout this article, we use additive and antagonistic as shorthand terms for increasing or decreasing the response observed with TCDD alone) behavior towards DRE binding with 10(-9) M TCDD, whereas most other PBDE congeners antagonized the action of TCDD. PBDEs 100 [penta], 153 [hexa present in octa mixture], and 183 [hepta present in octa mixture] were very weak activators of DRE binding; other congeners and the commercial "penta," "octa," and "deca" bromodiphenyl ether mixtures were inactive."
Chen G, Bunce NJ. Department of Chemistry and Biochemistry, University of Guelph, Guelph, Ontario, Canada N1G 2W1. Polybrominated diphenyl ethers as Ah receptor agonists and antagonists. Toxicol Sci. 2003 Dec;76(2):310-20. Epub 2003 Sep 26.

Doses of commercial octaBDE as low as 0.78 mumol/kg/day administered to rats for 90 days increased O-ethyl O-p-nitrophenyl phenylphosphonothioate (EPN) detoxification and p-nitroanisole demethylation. Higher doses also increased cytochrome P-450 and NADPH cytochrome c reductase. "Measurements made at 30 and 60 days after the last dose showed that these indicators of induced xenobiotic metabolism return to control levels slowly. The results demonstrate that these inducers are not only potent but that their effects may be long-lasting."
Carlson GP. Induction of xenobiotic metabolism in rats by brominated diphenyl ethers administered for 90 days. Toxicol Lett. 1980 Aug;6(3):207-12.

Doses of commercial octaBDE of 0.1 mmol/kg/day administered to rats for 14 days increased O-ethyl O-p-nitrophenyl phenylphosphonothioate (EPN) detoxification, p-nitroanisole demethylation, NADPH-cytochrome c reductase, cytochrome P-450, liver weight, UDP-glucuronyltransferase and benzo[a]pyrene hydroxylase.
Carlson GP. Induction of xenobiotic metabolism in rats by short-term administration of brominated diphenyl ethers. Toxicol Lett. 1980 Jan;5(1):19-25.

Liver

"The information concerning the effects of repeated oral and inhalation exposure to OBDPO comes from studies in rats involving administration of commercial OBDPO. These studies consistently indicate that the liver is the key target organ affected by OBDPO. The effects observed include increases in liver weight and liver enlargement, cellular microscopic changes, scattered incidence of hyperplastic nodules during the withdrawal period (8 weeks and 6 months) and induction of a range of liver enzymes. It was also shown that OBDPO exhibits a strong porphyrinogenic effect in vitro (see Section 4.1.2.9.1)." "Dose-related increases in total bromine levels in the liver were observed after 4 and 13 weeks of oral treatment from 100 ppm. Following 2 weeks of inhalation exposure, increase in total bromine concentrations were reported in the liver and in the fat and the lung as well. Moreover it was shown that fat and lung accumulate OBDPO to a greater extent than the liver." "Regarding systemic toxicity, the liver changes produced by commercial OBDPO, apparent within 4 and 13 weeks of repeated

oral dosing and within 14 days and 90 days of inhalation exposure, are observed in the latter study from 16 mg/m3 (analytical concentration)."
European Union Risk Assessment Report, Diphenyl ether, octabromo derivative, Risk Assessment, Final Report 2003, France and United Kingdom, 2003

(c) Environmental fate **(provide summary information and relevant references)**

Chemical/physical properties

Persistence

This study sought to model serum half-lives of PBDEs with 7 – 10 bromines in rubber workers and electronic dismantlers with occupational exposures. "The calculated apparent half-life for decabromodiphenyl ether (BDE-209) was 15 days (95% confidence interval, 11-18 days). The three nona-BDEs and four octa-BDE congeners were found to have half-lives of 18-39 and 37-91 days, respectively."
Thuresson K, Hoglund P, Hagmar L, Sjodin A, Bergman A, Jakobsson K. Department of Environmental Chemistry, Stockholm University, Stockholm, Sweden. Apparent half-lives of hepta- to decabrominated diphenyl ethers in human serum as determined in occupationally exposed workers. Environ Health Perspect. 2006 Feb;114(2):176-81.

Penta-47, 99, 100, 153, and 154 dominated the constituents measured in surface soils from remote and rural woodland and grassland locations from the UK and Norway. "Concentrations ranged between 65 and 12 000 sigma(ALL)PBDE ng kg(-1) dry weight." "BDE-183, a marker for the octa-BDE mix, was detected at concentrations ranging from <9 to 7000 (median approximately 50 ng kg(-1)). In most soils, it made a minor contribution to the sigma(ALL)PBDE concentration, but it was a major component in some samples from northern England. Forest soils tended to have higher concentrations than grasslands. Underlying the average soil composition, some differences in the congener pattern were observed."
Hassanin A, Breivik K, Meijer SN, Steinnes E, Thomas GO, Jones KC. Department of Environmental Science, Institute of Environmental and Natural Sciences, Lancaster University, Lancaster LA1 4YQ, UK. PBDEs in European background soils: levels and factors controlling their distribution. Environ Sci Technol. 2004 Feb 1;38(3):738-45.

This study measured 41 PBDE congeners in organic window films from a transect than ran north from Toronto, Canada. "For exterior films, urban sigmaPBDE concentrations were approximately 10x greater than rural concentrations, indicating an urban-rural gradient and greater PBDE sources in urban areas. Urban films ranged from 2.5 to 14.5 ng/m2 (mean = 9.0 ng/ m2), excluding the regional "hotspot" Electronics Recycling Facility, compared to 1.1 and 0.56 ng/m2 at the Suburban and Rural sites. Interior urban films (mean = 34.4 ng/m2) were 3 times greater than rural films (10.3 ng/m2) and were representative of variations in building characteristics. Indoor films were 1.5-20 times greater than outdoor films, consistent with indoor sources of PBDEs and enhanced degradation in outdoor films. Congener profiles were dominated by BDE-209 (51.1%), consistent with deca-BDE as the main source mixture, followed by congeners from the

penta-BDE mixture (BDE-99:13.6% and -47:9.4%) and some octa-BDE (BDE-183:1.5%). Congener patterns suggest a degradative loss of lower brominated compounds in outdoor films versus indoor films. Gas-phase air concentrations were back-calculated from film concentrations using the film-air partition coefficient (K(FA)). Mean calculated air concentrations were 4.8 pg/m3 for outdoor and 42.1 pg/m3 for indoor urban sites, indicating that urban indoor air is a source of PBDEs to urban outdoor air and the outdoor regional environment."
Butt CM, Diamond ML, Truong J, Ikonomou MG, ter Schure AF. Department of Geography, University of Toronto, Toronto, Ontario, Canada M5S 3G3. Spatial distribution of polybrominated diphenyl ethers in southern Ontario as measured in indoor and outdoor window organic films. Environ Sci Technol. 2004 Feb 1;38(3):724-31.

How are chemical/physical properties and persistence linked to environmental transport, transfer within and between environmental compartments, degradation and transformation to other chemicals?

OctaBDE formed by debromination

The debromination of BDE-209 (deca) in European starling was measured along with accumulation and tissue-specific distribution. "In addition to BDE 209, other PBDE congeners, particularly octa- and nonaBDEs, were also present in the muscle and liver, suggesting bioformation from BDE 209. To our knowledge, these results are the first indications for the debromination of BDE 209 in birds."
Van den Steen E, Covaci A, Jaspers VL, Dauwe T, Voorspoels S, Eens M, Pinxten R. Department of Biology, University of Antwerp (Campus Drie Eiken), Universiteitsplein 1, 2610 Wilrijk, Belgium. Accumulation, tissue-specific distribution and debromination of decabromodiphenyl ether (BDE 209) in European starlings (Sturnus vulgaris). Environ Pollut. 2007 Jan 16

This study examined the debromination of decabromodiphenyl ether (decaBDE or BDE209) to other metabolites including octaBDE in juvenile rainbow trout. Fish were analyzed after exposure to decaBDE for five months in the diet and BDE209 was most concentrated in the liver. "In addition to BDE 209, several hepta-, octa-, and nonaBDE congeners also accumulated in rainbow trout tissues over the same period as a result of BDE 209 debromination." "Extracts of the rainbow trout whole body homogenates were compared with extracts from a previous experiment with common carp. This comparison revealed that BDE 202 (2,2',3,3',5,5',6,6'-octabromodiphenyl ether) was a dominant debromination product in both studies. To determine whether the observed debromination was metabolically driven, liver microsomal fractions were prepared from both common carp and rainbow trout. Analysis of the microsomal fractions following incubation with BDE 209 revealed that rainbow trout biotransformed as much as 22% of the BDE 209 mass, primarily to octa- and nonaBDE congeners. In contrast, carp liver microsomes biotransformed up to 65% of the BDE 209 mass, primarily down to hexaBDE congeners. These microsomal incubations confirm a metabolic pathway for BDE 209 debromination."

Stapleton HM, Brazil B, Holbrook RD, Mitchelmore CL, Benedict R, Konstantinov A, Potter D. Duke University, Nicholas School of the Environment and Earth Sciences, Durham, North Carolina, USA. heather.stapleton@duke.edu In vivo and in vitro debromination of decabromodiphenyl ether (BDE 209) by juvenile rainbow trout and common carp. Environ Sci Technol. 2006 Aug 1;40(15):4653-8.

Debromination of decaBDE and octaBDE was studied in two species of anaerobic bacteria: Sulfurospirillum multivorans and Dehalococcoides species. “Hepta- and octa-BDEs were produced by the S. multivorans culture when it was exposed to deca-BDE, although no debromination was observed with the octa-BDE mixture. In contrast, a variety of hepta- through di-BDEs were produced by Dehalococcoides-containing cultures exposed to an octa-BDE mixture, despite the fact that none of these cultures could debrominate deca-BDE. The more toxic hexa-154, penta-99, tetra-49, and tetra-47 were identified among the debromination products. Because the penta-BDE congeners are among the most toxic PBDEs, debromination of the higher congeners to more toxic products in the environment could have profound implications for public health and for the regulation of these compounds.”
He J, Robrock KR, Alvarez-Cohen L. Department of Civil and Environmental Engineering, University of California at Berkeley, Berkeley, California 94720-1710, USA. Microbial reductive debromination of polybrominated diphenyl ethers (PBDEs). Environ Sci Technol. 2006 Jul 15;40(14):4429-34

Debromination of decaBDE (BDE-209) was tested under anaerobic conditions by incubating sewage sludge with and without primers for 238 days. “Formation of two nonabromodiphenyl ether and six octabromodiphenyl ether congeners proved that BDE-209 underwent reductive debromination in these experiments. Debromination occurred at the para and the meta positions, whereas debromination at the ortho position was not statistically significant.” “No significant change of the BDE-209 concentration and no formation of lower brominated congeners was observed in sterile control experiments. To our knowledge, this is the first report demonstrating microbially mediated reductive debromination of BDE-209 under anaerobic conditions.”
Gerecke AC, Hartmann PC, Heeb NV, Kohler HP, Giger W, Schmid P, Zennegg M, Kohler M. Laboratory of Organic Chemistry, Swiss Federal Institute for Materials Science and Technology (Empa), Uberlandstrasse 129, 8600 Dubendorf, Switzerland. andreas.gerecke@empa.ch Anaerobic degradation of decabromodiphenyl ether. Environ Sci Technol. 2005 Feb 15;39(4):1078-83.

Bio-concentration or bio-accumulation factor, based on measured values **(unless monitoring data are judged to meet this need)**

This study examined the absorption and elimination of PBDEs in chicken eggs by feeding hens with 3.4 mg/kg PBDEs and measuring excretion of the substances. “Sixty-two percent of ingested 2,2',4,4'-tetraBDE (BDE-47) were found in excreta after two weeks, suggesting a reductive debromination of PBDEs in the digestive tract. PBDE level in eggs increased during five weeks and reached 24mug/g fat. After then, levels

decreased to 3mug/g fat at the end of the trial. PBDE bioconcentration factors estimated for abdominal fat varied from 0.7 for BDE-47 to 2 for BDE-183."
Pirard C, Pauw ED. CART Mass Spectrometry Laboratory, Chemistry Department, University of Liege, Allee de la Chimie 3, B-6c, B-4000 Liege, Belgium. Absorption, disposition and excretion of polybrominated diphenyl ethers (PBDEs) in chicken. Chemosphere. 2007 Jan;66(2):320-5

This study examined biomagnifications of PBDEs and PCBs in fish from the Baltic Sea and north Atlantic. "In the Baltic Sea material, consisting of zooplankton, sprat, herring and salmon, we report biomagnification of all PCB congeners but PCB #209 and of PBDEs with 3-6 or 7 bromine atoms. Higher brominated PBDEs and PCB 209 did not biomagnify likely due to their high molecular weights or sizes and subsequent inefficient dietary uptake in fish. If salmon was excluded from the statistical analysis, strong biomagnification of PCB #209 was evident, indicating species differences in biomagnification." "Higher PBDE concentrations in the Baltic compared to the Atlantic Sea salmon were also found, but with a larger variation between congeners. Nona- to deca-BDEs were found in most investigated samples, which illustrates the bioavailability of these compounds. Unidentified penta-, hexa-, hepta-, and octa- BDEs were found in several samples."
Burreau S, Zebuhr Y, Broman D, Ishaq R. Department of Zoology, Stockholm University, SE-106 91 Stockholm, Sweden. Biomagnification of PBDEs and PCBs in food webs from the Baltic Sea and the northern Atlantic Ocean. Sci Total Environ. 2006 Aug 1;366(2-3):659-72. 2006 Mar 31.

This study examined biomagnification of PBDEs and PCBs in pike, perch, and roach from the Baltic Sea. "Tri- to hepta-BDEs also biomagnify but showed a maximum biomagnification for the penta-BDEs (log Kow 6.46-6.97). The biomagnification of hexa- to hepta-PBDEs was negatively correlated with degree of bromination, likely due to large molecular size or high molecular weight (644-959 Da). Octa-, nona- and deca-BDEs did not biomagnify but were found in two (octa-BDE) and three (nona- and deca-BDEs) of the species, respectively. Increased size of pike is correlated with increased lipid weight based PCB and PBDE concentrations in males but not in females and mean PCB and PBDE concentrations in males are generally higher than in females."
Burreau S, Zebuhr Y, Broman D, Ishaq R. Department of Zoology, Stockholm University, Stockholm SE-106 91, Sweden. Biomagnification of polychlorinated biphenyls (PCBs) and polybrominated diphenyl ethers (PBDEs) studied in pike (Esox lucius), perch (Perca fluviatilis) and roach (Rutilus rutilus) from the Baltic Sea. Chemosphere. 2004 May;55(7):1043-52.

(d) Monitoring data **(provide summary information and relevant references)**

Humans

This study examined 92 blood samples from 30 incinerator workers, 51 nearby residents, and 11 controls for PBDEs. "The PBDE levels and congener profiles detected in incinerator workers were not distinctly different from those found in the general population. In all groups tested, BDE-47 was dominant (mean contribution=32.5%)

followed by BDE-153 (23.6%) and relatively high portions of BDE-183 (16.5%) were found. No strong trend was observed between PBDE levels and a number of key biological factors examined in this study, however, weak correlations were observed in PBDE levels measured against dietary habits, particularly in fish consumption frequency and gender."
Lee SJ, Ikonomou MG, Park H, Baek SY, Chang YS. School of Environmental Science and Engineering, POSTECH, Pohang 790-784, Republic of Korea. Polybrominated diphenyl ethers in blood from Korean incinerator workers and general population. Chemosphere. 2006 Nov 14

"Human adipose tissue samples (n=52) collected in New York City during 2003-2004 were analyzed for the presence of polybrominated diphenyl ethers (PBDEs) and polychlorinated biphenyls (PCBs). Concentrations of PBDEs in adipose tissues ranged from 17 to 9630 ng/g, lipid wt (median: 77; mean: 399 ng/g, lipid wt; sum all di- through hexaBDE congeners). Average PBDE concentrations in human adipose tissues from New York City were 10- to 100-times greater than those reported for European countries. A concentration of 9630 ng/g, lipid wt, found in a sample of adipose tissue, is one of the highest concentrations reported to date. PBDE 47 (2,2',4,4'-tetraBDE) was the major congener detected in human tissues, followed by PBDE congeners #99 (2,2',4,4',5-penta BDE), 100 (2,2',4,4',6-pentaBDE), and 153 (2,2',4,4',5,5'-hexaBDE). A few individuals contained PBDE 153 as the predominant congener in total PBDE concentrations, suggesting alternative exposure sources, possibly occupational. Principal component analysis of PBDE congener composition in human adipose tissues revealed the presence of five clusters, each characterized by varying composition. No significant difference was found in the concentrations of PBDEs between genders. Concentrations of PBDEs were, on average, similar to those for PCBs in human adipose tissues, and substantially higher when PBDE outliers were retained. PBDE and PCB concentrations were not correlated. PBDE concentrations did not increase with increasing age of the subjects, whereas concentrations of PCBs increased with increasing age in males but not in females in this study. These results suggest differences between PBDEs and PCBs in their sources or time course of exposure and disposition. The presence of comparable or greater concentrations of PBDEs, relative to PCBs, highlights the importance of recent voluntary and regulatory efforts to cease production of commercial penta- and octa-BDE in North America, although these efforts do not address continuing emissions from existing sources, such as polyurethane foams."
Johnson-Restrepo B, Kannan K, Rapaport DP, Rodan BD. Wadsworth Center, New York State Department of Health and Department of Environmental Health Sciences, State University of New York at Albany, Empire State Plaza, P.O. Box 509, Albany, New York 12201-0509, USA. Polybrominated diphenyl ethers and polychlorinated biphenyls in human adipose tissue from New York. Environ Sci Technol. 2005 Jul 15;39(14):5177-82.

This follow-up study examined occupational exposure to PBDEs in an electronics recycling plant after industrial hygiene measures were enacted. Twelve workers that participated in the previous study were used for comparison. "Even though the amount of processed goods had doubled in 2000 as compared to 1997, there was a significant

decrease in the serum levels of BDE-183 and BDE-209." "In contrast to the decrease of higher brominated diphenyl ethers, the concentrations of BDE-47 did not significantly change. For BDE-153, the cross-sectional study indicated no change, whereas the longitudinal follow up indicated a significant increase. This study shows that the industrial hygiene improvements clearly reduced the occupational exposure to BDE-183 and BDE-209 at the plant. Still, the levels of hexa- to nonaBDEs but not BDE-209 were elevated, compared to referents with no occupational exposure."
Thuresson K, Bergman K, Rothenbacher K, Herrmann T, Sjolin S, Hagmar L, Papke O, Jakobsson K. Department of Environmental Chemistry, Stockholm University, SE-106 91 Stockholm, Sweden. Polybrominated diphenyl ether exposure to electronics recycling workers--a follow up study. Chemosphere. 2006 Sep;64(11):1855-61. 2006 Mar 9

PBDEs, dioxins, and PCBs were measured in the blood of 13 workers at two different municipal waste incinerator (MWI) plants and 22 residents living near the incinerators. "The concentrations of PBDEs were found to be slightly higher in the blood of incineration workers (8.61-46.05 ng/g lipid; mean, 19.33 ng/g lipid; median, 15.94 ng/g lipid) in comparison to that of residents from the general population (7.24-28.89 ng/g lipid; mean, 15.06 ng/g lipid; median, 14.34 ng/g lipid)." "The presence of the BDE 183 congener was characteristic in the blood of workers from an electronic dismantling facility in MWIs."
Kim BH, Ikonomou MG, Lee SJ, Kim HS, Chang YS. School of Environmental Science and Engineering, Pohang University of Science and Technology, San 31 Hyojadong, Namku, Pohang 790-784, Republic of Korea. Concentrations of polybrominated diphenyl ethers, polychlorinated dibenzo-p-dioxins and dibenzofurans, and polychlorinated biphenyls in human blood samples from Korea. Sci Total Environ. 2005 Jan 5;336(1-3):45-56

While the goal of this study was to assess exposure of rubber production workers to decaBDE, pentaBDE and octaBDE were also measured. "Concentrations of all nonabromodiphenyl ethers (nonaBDEs) and several octabrmodiphenyl ethers (octaBDEs) congeners, including BDE-203, were also elevated among the rubber workers, with 2.5- to 11-fold higher median concentrations, compared to the referents. The results confirm a significant uptake of BDE-209 in the workers exposed to DecaBDE and indicate a potential for in vivo formation of lower BDEs in these persons."
Thuresson K, Bergman A, Jakobsson K. Department of Environmental Chemistry, Stockholm University, SE-10691 Stockholm, Sweden. kaj.thuresson@mk.su.se Occupational exposure to commercial decabromodiphenyl ether in workers manufacturing or handling flame-retarded rubber. Environ Sci Technol. 2005 Apr 1;39(7):1980-6.
Personal air monitoring of workers in a recycling facility was performed with measurements of 22 PBDEs. "The most abundant congeners of PBDE was #209 (<0.7-61 ng m(-3)), #183 (<0.1-32 ng m(-3)) indicating the use of the commercial octaBDE mixture, followed by PBDE #99 and #47 (<1.3-25 and <0.9-16 ng m(-3), respectively)." "The workers represented three different categories: dismantlers, other workers and unexposed. There was a significant difference ($p < 0.05$ with the Mann-Whitney test) among the dismantlers and the unexposed categories for PBDE congeners #47, #100,

#99, #154; #153, #183, #209 and BTBPE. Another observation was that the air concentrations of PBDEs and BTBPE in the breathing zone were negatively correlated ($p < 0.05$) to the amount of recycled material (in kg)."
Pettersson-Julander A, van Bavel B, Engwall M, Westberg H. Man-Technology-Environment Research Centre, Dept. of Natural Sciences, Orebro University, 70182, Orebro, Sweden. anneli.julander@nat.oru.se Personal air sampling and analysis of polybrominated diphenyl ethers and other bromine containing compounds at an electronic recycling facility in Sweden. J Environ Monit. 2004 Nov;6(11):874-80. 2004 Oct 21.

Breast milk from 47 mothers from Texas, USA was analyzed for 13 PBDE congeners. Sigma PBDE concentrations varied from 6.2 – 419 ng/g lipid; with a median of 34 ng/g lipid; and a mean of 73.9 ng/g lipid. PBDE138 concentrations varied from not detected – 6386 ng/g lipid. PBDE153 concentrations varied from 0.4 –21.8 ng/g lipid. PBDE154 concentrations varied from 0.06 –7.21 ng/g lipid. PBDE183 concentrations varied from not detected – 1.32 ng/g lipid with a median of ng/g lipid; and a mean of ng/g lipid. The authors note that the 47 women in this study had much higher levels of PBDEs in their breast milk compared to Europeans.
Schecter A, Pavuk M, Papke O, Ryan JJ, Birnbaum L, Rosen R. University of Texas Health Sciences Center, School of Public Health, Dallas Regional Campus, Dallas, Texas 75390, USA. arnold.schecter@utsouthwestern.edu Polybrominated diphenyl ethers (PBDEs) in U.S. mothers' milk. Environ Health Perspect. 2003 Nov;111(14):1723-9.

This study examined six PBDE congeners (47, 99, 100, 153, 154, and 183) in fetal and maternal sera in 12 paired samples of maternal and cord blood. BDE153, 154, and 183 were found in fetal serum at levels ranging from 1.0 – 120 ng/g, 0.2 – 7.2 ng/g, and 0.0 – 4.8 ng/g respectively. BDE153, 154, and 183 were found in maternal serum at levels ranging from 1.0 - 83 ng/g, 0.0 – 6.1 ng/g, and 0.0 – 2.7 ng/g respectively. The authors conclude that women in North America are exposed to much higher levels of PBDEs than European women.
Mazdai A, Dodder NG, Abernathy MP, Hites RA, Bigsby RM. Department of Obstetrics and Gynecology, Indiana University School of Medicine, Indianapolis, Indiana, USA; and Department of Chemistry and School of Public and Environmental Affairs, Indiana University, Bloomington, Indiana, USA Polybrominated Diphenyl Ethers in Maternal and Fetal Blood Samples Environ Health Perspect 2003 111:1249–1252

PBDEs, PBDDs, and PBDFs were measured in human adipose tissues collected in 1970 and 2000. Seven PBDE congeners were found including BDE28, BDE47, BDE99, BDE100, BDE153, BDE154, and BDE183. "Median concentrations (ranges) of PBDEs showed a significant increase from 29.2 (6.8-78.4) pg/g l.w. in 1970 to 1288 (466-2,753) pg/g l.w. in 2000. BDE-47, the major congener of PBDEs, was 56.2% and 35.6% of the total in 1970 and 2000, respectively, whereas the BDE-153 was < 1% and 29.7% of the total in 1970 and 2000, respectively. This may indicate that the source of PBDEs had changed during this period."
Choi JW, Fujimaki TS, Kitamura K, Hashimoto S, Ito H, Suzuki N, Sakai S, Morita M. Polybrominated dibenzo-p-dioxins, dibenzofurans, and diphenyl ethers in Japanese human adipose tissue. Environ Sci Technol. 2003 Mar 1;37(5):817-21.

This study investigated exposure to flame retardants among 19 computer technicians. “The computer technicians had serum concentrations of BDE-153, BDE-183 and BDE-209 that were five times higher than those reported among hospital cleaners and computer clerks. The median levels observed among the computer technicians were 4.1, 1.3, and 1.6 pmol/g lipid weight, respectively. In contrast, for BDE-47 there was no difference between the computer technicians and the others. BDE-100, BDE-203, and three structurally unidentified octa-BDEs and three nona-BDEs, were present in almost all samples from the computer technicians. Further, TBBPA was detected in 8 out of 10 samples. The levels of BDE-153, BDE-183, and one of the octa-BDEs were positively correlated with duration of computer work among technicians. On a group level an exposure gradient was observed, from the least exposed cleaners to the clerks, and to the highest exposed group of computer technicians. A dose (duration of computer work)-response relationship among computer technicians was demonstrated for some higher brominated PBDE congeners. Thus, it is evident that PBDEs used in computers and electronics, including the fully brominated BDE-209, contaminate the work environment and accumulate in the workers tissues.”
Jakobsson K, Thuresson K, Rylander L, Sjodin A, Hagmar L, Bergman A. Department of Occupational and Environmental Medicine, Lund University Hospital, Sweden. kristina.jakobsson@ymed.lu.se Exposure to polybrominated diphenyl ethers and tetrabromobisphenol A among computer technicians. Chemosphere. 2002 Feb;46(5):709-16.

PBDEs were measured in workers from an electronics dismantling facility, in the production of printed circuit boards, or as laboratory personnel. “The subjects working at the electronics dismantling plant had significantly higher plasma levels of TBBP-A and BDE-153 compared to the other groups, and the heptabrominated congener BDE-183 was only detected in plasma from this group.” “The total amounts of the seven BDEs were 8.8, 3.9 and 3.0 ng g-1 lipids for the group of electronics dismantlers, circuit board producers and laboratory personnel, respectively.”
Thomsen C, Lundanes E, Becher G. National Institute of Public Health, P.O. Box 4404, Nydalen, N-0403 Oslo, Norway. cathrine.thomsen@folkehelsa.no Brominated flame retardants in plasma samples from three different occupational groups in Norway. J Environ Monit. 2001 Aug;3(4):366-70.

“Serum samples collected in 1988 from U.S. blood donors were analyzed for polybrominated diphenyl ethers (PBDEs) and polychlorinated and polybrominated biphenyls (PCBs and PBBs). The levels of the PBDEs are reported for the first time in serum from the U.S. population. The median concentrations and range of 2,2',4,4'-tetrabromodiphenyl ether (BDE-47); 2,2',4,4',5,5'-hexabromodiphenyl ether (BDE-153); 2,2',3,4,4',5',6-heptabromodiphenyl ether (BDE-183); and decabromodiphenyl ether (BDE-209) were 1.3 (<0.8-49); 0.54 (0.13-3.1); 0.24 (0.12-1.8); and <1 (<1-35) pmol/g lipid weight (l.w.), respectively.”
Sjodin A, Patterson DG Jr, Bergman A. Department of Environmental Chemistry, Stockholm University, Sweden. asjodin@cdc.gov Brominated flame retardants in serum from U.S. blood donors. Environ Sci Technol. 2001 Oct 1;35(19):3830-3.

Animals

Sixty fish samples from six rivers and three estuaries in Taiwan were examined for PBDEs. The dominant congener in all waters was pentaBDE. However, BDE-154 and BDE-183 were the predominant congeners in some of the sampled species. “These results are somewhat different from those from other countries, where the pattern is typically BDE-47>99>100>154, 153, and is postulated to be due to the extensive use of octa-BDE rather than penta-BDE in Taiwan. The average concentration distribution across all samples of the sum of PBDE congeners ranged from 30.6ng/g lipid to 281ng/g lipid. The concentrations of PBDEs in fishes reported here are higher than those reported from European countries, but lower than those from the United States.”
Peng JH, Huang CW, Weng YM, Yak HK. Environmental Analysis Laboratory, Environmental Protection Administration, No. 260, Sec 3, Ming Tsu Rd., Chung-Li, Taiwan 32024, Republic of China; Green Chemistry Lab, Department of Chemistry, Chung Yuan Christian University, Chung-Li, Taiwan 32023, Republic of China. Determination of polybrominated diphenyl ethers (PBDEs) in fish samples from rivers and estuaries in Taiwan. Chemosphere. 2007 Jan;66(10):1990-1997.

“In the present study, we have analyzed muscle, liver, and adipose tissue of 33 red foxes from Belgium for their content of polybrominated diphenyl ethers (PBDEs). Median sums of seven tri- to hepta-BDEs (BDE 28, BDE 47, BDE 99, BDE 100, BDE 153, BDE 154, and BDE 183) were 2.2, 2.4, and 3.4 ng/g lipid weight in adipose tissue, liver, and muscle, respectively. These levels were lower than those found in various species of voles and mice, the main prey species of the red fox. This is probably related to the high capacity of the foxes to metabolize and eliminate lower brominated congeners. BDE 209 generally dominated the PBDE congener profiles in the red fox samples… Other abundant congeners were BDE 153 and BDE 47, which prevail in other terrestrial species.”
Voorspoels S, Covaci A, Lepom P, Escutenaire S, Schepens P. Toxicological Centre, University of Antwerp, Universiteitsplein 1, 2610 Wilrijk, Belgium, Umweltbundesamt, P.O. Box 33 00 22, D-14191 Berlin, Germany. stefan.voorspoels@ua.ac.be Remarkable findings concerning PBDEs in the terrestrial top-predator red fox (Vulpes vulpes) Environ Sci Technol. 2006 May 1;40(9):2937-43

This study measured PCBs, PBDEs and organochlorine pesticides in liver and muscle samples from seven species of aquatic and terrestrial predatory birds from Flanders, Belgium. “BDE 183 and BDE 209 were only measured in the terrestrial birds. These results indicate that terrestrial birds may be more exposed to higher brominated BDE congeners than aquatic species.”
Jaspers VL, Covaci A, Voorspoels S, Dauwe T, Eens M, Schepens P. Department of Biology, University of Antwerp, Campus Drie Eiken, Universiteitsplein 1, 2610 Wilrijk, Belgium. veerle.jaspers@ua.ac.be Brominated flame retardants and organochlorine pollutants in aquatic and terrestrial predatory birds of Belgium: levels, patterns, tissue distribution and condition factors. Environ Pollut. 2006 Jan;139(2):340-52. 2005 Jul 6

PBDEs were measured in 13 sediments and 9 samples of green-lipped mussels (Perna viridis) in the marine environment of Hong Kong. “The Sigma15PBDEs in sediments

ranged between 1.7 and 53.6 ng g(-1) dry wt, with the highest concentrations located around the most heavily populated areas of Victoria Harbour and Sai Kung, while the lowest concentrations of Sigma15PBDEs were found at more remote locations of Sha Tau Kok, Wong Chuk Bay, Castle Peak Bay, and Gold Coast. Sigma15PBDEs ranged from 27.0 to 83.7 ng g(-1) dry wt of mussel tissues. Although not identical, most of the congeners in sediments were found in mussel tissues, with BDE-47, BDE-99, BDE-153 and BDE-183 being the most prominent in both matrices. On the basis of a literature survey, the concentrations of PBDEs reported in Hong Kong sediments and mussel tissues are amongst the highest in the world."
Liu Y, Zheng GJ, Yu H, Martin M, Richardson BJ, Lam MH, Lam PK. Department of Biology and Chemistry, Centre for Coastal Pollution and Conservation, City University of Hong Kong, Tat Chee Avenue, Kowloon, Hong Kong SAR, People's Republic of China. Polybrominated diphenyl ethers (PBDEs) in sediments and mussel tissues from Hong Kong marine waters. Mar Pollut Bull. 2005 Nov;50(11):1173-84. 2005 Jun 13

PBDEs were measured in eggs from marine and freshwater birds from British Columbia, Canada sampled from 1983 – 2002. Birds included great blue herons (Ardea herodias), double-crested cormorants (Phalacrocorax auritus), osprey (Pandion haliaetus), and Leach's storm-petrel (Oceanodroma leucorhoa). Total average PBDE concentrations were highest in heron eggs at 455 ug/kg wet weight. "PBDEs increased exponentially with a doubling time of 5.7 years in eggs of both herons and cormorants. Over this period of increasing PBDEs, major chlorinated hydrocarbons, such as PCBs and DDE, were stable or decreased. The PBDE pattern was relatively consistent in most years and sites, with BDEs 47 > 100 > 99 > 153 > 154 > 28 > 183. This was interpreted as evidence of technical pentaBDE formulations as primary sources of the contamination, with the octaBDE formulations as secondary." "At some locations, concentrations of pentabrominated congeners and mixtures in fish are approaching levels potentially toxic to fish-eating birds, based on rodent studies and calculations of dietary intake from fish data."
Elliott JE, Wilson LK, Wakeford B. Canadian Wildlife Service, 5421 Robertson Road, Delta, British Columbia V4K 3N2, Canada. john.elliott@ec.gc.ca Polybrominated diphenyl ether trends in eggs of marine and freshwater birds from British Columbia, Canada, 1979-2002. Environ Sci Technol. 2005 Aug 1;39(15):5584-91

This study examined PBDE content in the eggs of home-grown chickens from 11 sampling locations in Eastern Europe, Asia, Africa, Middle East, and the Americas. The sampling sites were close to areas such as municipal, medical, and hazardous waste incinerators, petrochemical plants, and a dump site. Levels of total PBDEs ranged from 0.8 – 106.8 ng/g lipid. Levels of BDE153 ranged from <0.05 – 1.94 ng/g lipid. The highest levels were observed in samples from Mozambique, Turkey, and the US. BDE183 varied from <0.15 – 8.97 ng/g lipid. The highest levels were measured in samples from Turkey, US, Mozambique, and Kenya. These results represent some of the first sampling data on PBDEs in developing countries, particularly in Africa and Asia outside of Japan.
Blake A. The next generation of POPs: PBDEs and Lindane, International POPs Elimination Network, 2005 http://www.ipen.org/ipenweb/library/4_4_cm_doc_1.html

"Several brominated flame retardants (BFRs) were analyzed in peregrine falcon eggs collected in 1987-1999, including the constituents of the technical polybrominated diphenyl ether (PBDE) products Penta (BDE-47, -99, -100, -153, -154), Octa (BDE-183), and Deca (BDE-209), hexabrominated biphenyl (BB-153), and hexabromocyclododecane (HBCD). The eggs represented females from three different breeding populations, northern Sweden, southwestern Sweden, and a captive breeding population. All BFRs analyzed for were found, including BDE-183 and -209, and concentrations were much higher in wild falcons (geometric mean sigmaPBDE, BB-153, and HBCD for northern/southern populations of 2200/2700, 82/77, and 150/250 ng/g lw, respectively) than in captive falcons (39, 8 ng/g lw, and not detected, respectively). This is the first time, to our knowledge, that BDE-183 and -209 have been quantified in high trophic level wildlife."
Lindberg P, Sellstrom U, Haggberg L, de Wit CA. Swedish Society for Nature Conservation, Box 4625, SE-116 91 Stockholm, Sweden. Higher brominated diphenyl ethers and hexabromocyclododecane found in eggs of peregrine falcons (Falco peregrinus) breeding in Sweden. Environ Sci Technol. 2004 Jan 1;38(1):93-6.

This study examined PBDEs in whitefish (Coregonus sp.) from eight Swiss lakes and in rainbow trout (Oncorhynchus mykiss) from four Swiss fish farms. "PBDE concentrations (sum of PBDE congeners BDE-28, BDE-47, BDE-99, BDE-100, BDE-153, BDE-154, and BDE-183) in filet from whitefish between 36 and 165 ng/g lipid weight (lw) were found, corresponding to wet weight (ww) concentrations of 1.6-7.4 ng/gww. PBDE contents in filet from farmed rainbow trout were significantly lower than in wild whitefish (12-24 ng/glw, 0.74-1.3 ng/gww), and the PBDE congener patterns were different for both species (a higher BDE-47 to BDE-99 ratio for farmed rainbow trout compared to wild whitefish was found). Whitefish PBDE levels [ng/glw] correlate better with the surface/volume ratio of the respective lakes (r(2)=0.70) than with other lake properties such as catchment area (size or number of inhabitants) or residence time, suggesting atmospheric deposition as an input pathway for PBDE."
Zennegg M, Kohler M, Gerecke AC, Schmid P. Swiss Federal Laboratories for Materials Testing and Research (EMPA), Laboratory of Organic Chemistry, Uberlandstrasse 129, 8600 Dubendorf, Switzerland. markus.zennegg@empa.ch Polybrominated diphenyl ethers in whitefish from Swiss lakes and farmed rainbow trout. Chemosphere. 2003 May;51(7):545-53.

PBDEs were measured in whelk (Buccinum undatum), seastar (Asterias rubens", hermit crab (Pagurus bernhardus), whiting (Merlangius merlangus), cod (Gadus Morhua), harbor seal (Phoca vitulina), and harbor porpoise (Phocoena phocoena). The major congeners detected include PBDE 28, 47, 99, 100, 153, and 154. PBDE183 was not detected. "The lipid-normalized levels of the six major PBDE congeners in fish were similar to the levels in the invertebrates, but a biomagnification step in concentrations of generally more than an order of magnitude occurred from gadoid fish to marine mammals. Based on the limited number of samples, no differences could be observed between harbor seal and harbor porpoise. In summary, the results in three species of sentinel invertebrates from a network of stations covering a major part of the North Sea basin showed that the estuary

of the river Tees at the UK East coast is a major source for tri- to hexa-PBDEs. Throughout the food-chain, the most marked increase in (lipid-normalized) levels of all six PBDE congeners occurred from predatory (gadoid) fish to marine mammals, agreeing with the transition from gill-breathing to lung-breathing animals. This has serious consequences for the route of elimination of POPs, since their elimination from the blood into the ambient seawater via the gill-membrane is no longer possible."
Boon JP, Lewis WE, Tjoen-A-Choy MR, Allchin CR, Law RJ, De Boer J, Ten Hallers-Tjabbes CC, Zegers BN. Royal Netherlands Institute for Sea Research (NIOZ), P.O. Box 59, 1790 AB Den Burg, Texel, The Netherlands. boon@nioz.nl Levels of polybrominated diphenyl ether (PBDE) flame retardants in animals representing different trophic levels of the North Sea food Web. Environ Sci Technol. 2002 Oct 1;36(19):4025-32.

"Polybrominated diphenyl ethers (PBDEs) were identified in fish collected from the Detroit River, MI and Des Plaines Rivers, IL. In the Detroit River fish, carp and large mouth bass, the congener patterns were dominated by the 2,2',4,4'-tetrabromo (BDE-47) congener, however, in Des Plaines River carp the dominant isomers were the heptabromo congeners BDE-181 and BDE-183 and lesser amounts of another heptabromo congener, BDE-190, and two hexabromo congeners, BDE-154 and BDE-153. Three possible sources exist for these less-commonly identified PBDE congeners: (a) waste discharge from manufacturing or discarded products near the river, (b) public owned treatment work (POTW) effluents which constitute more than 75% of the flow in the Des Plaines River, (c) or formation of these congeners by debromination of in-place deposits of decabromodiphenyl ether. Average concentration totals (sum of concentrations for seven of the dominant PBDE congeners) were similar on a wet weight bases for the carp (5.39 ng/g wet weight) and large mouth bass (5.25 ng/g) in the Detroit River samples; however, the bass were significantly higher, p = 0.01, when compared on a lipid basis (bass--163 ng/g vs. carp--40.5 ng/g lipid weight). Some of the PBDE congeners were positively correlated with increasing lipid levels in both fish species. Average total PBDE concentrations in the carp from the Des Plaines River (12.48 ng/g wet weight) were significantly higher, p = 0.01, than in carp from the Detroit River."
Rice CP, Chernyak SM, Begnoche L, Quintal R, Hickey J. US Department of Agriculture, ARS-Beltsville, Environmental Quality Laboratory, MD 20705, USA. ricec@ba.ars.usda.gov Comparisons of PBDE composition and concentration in fish collected from the Detroit River, MI and Des Plaines River, IL. Chemosphere. 2002 Nov;49(7):731-7.

"Geographical distribution of brominated diphenyl ether (BDE) flame retardants in the North American Great Lakes ecosystem in 2000 was determined by analysis of herring gull eggs (13 egg pools) from a network of 15 monitoring colonies scattered throughout the lakes and connecting channels. sigmaBDEs were found at concentrations ranging from 192 to 1,400 microg/kg, mean of 662 +/- 368 microg/kg (wet weight of egg contents). Highest concentrations were found in northern Lake Michigan and Toronto harbor (1,000-1,400 microg/kg) and lowest in Lake Huron and Lake Erie (192-340 microg/kg). The distribution suggested that input from large urban/ industrial areas through air or water emissions contributes local contamination to the herring gull food web in addition to background levels from regional/global transport. The congener

composition was similar among sampling sites. Major congeners were BDE-47 (43%), BDE-99 (26%), BDE-100 (13%) BDE-153 (11%), BDE-154 (4%), BDE-183 (2%) and BDE-28 (1%). Temporal trends of BDE contamination, 1981-2000, were established by analysis of archived herring gull eggs (10 egg pools) from colonies in northern Lake Michigan, Saginaw Bay, Lake Huron and eastern Lake Ontario. BDE-47, -99 and -100, and BDE-153, -154 and -183 concentrations were grouped separately for analysis because these two groups had different trends and are primarily associated with the Penta BDE and Octa BDE flame retardant formulations, respectively." "SigmaBDE154, 153, 183 concentrations generally increased but varied in an erratic fashion among sites and decreased as a fraction of sigmaBDE over time. Concentrations of sigmaBDE154,153,183 were 100-200 microg/kg in eggs from all three colonies in 2000." Norstrom RJ, Simon M, Moisey J, Wakeford B, Weseloh DV. Environment Canada, National Wildlife Research Centre, 100 Gamelin Boulevard, Hull, Quebec KIA 0H3, Canada. Ross.Norstrom@ec.gc.ca Geographical distribution (2000) and temporal trends (1981-2000) of brominated diphenyl ethers in Great Lakes hewing gull eggs. Environ Sci Technol. 2002 Nov 15;36(22):4783-9.

(e) Exposure in local areas **(provide summary information and relevant references)**

- general

"Children are exposed to PBDEs through diet, mainly through fish, meat and milk. Total dietary exposure of children in Europe was calculated to be 2-3 ng/kg b.w./day. For nursing infants the main source of PBDE exposure is breast milk; exposure levels are around 15 ng/kg b.w./day. PBDE exposure levels in North America are 10 to a 100 times higher. Because of their persistence and their similarity to polychlorinated biphenyls (PCBs), concern has been raised about the effects of PBDEs on human health. Exposure to penta- and octa-BDE led to learning impairment and impaired motor behaviour in rodents. Exposure to penta-, octa- and also deca-BDE caused effects on thyroid homeostasis in animals."
Zuurbier M, Leijs M, Schoeters G, Ten Tusscher G, Koppe JG. Public Health Services Gelderland Midden, Arnhem, The Netherlands. Children's exposure to polybrominated diphenyl ethers. Acta Paediatr Suppl. 2006 Oct;95(453):65-70.

"House dust was analyzed from the family vacuum cleaners of 68 of the same 74 randomly selected homes, in Ottawa, Canada during the winter of 2002-2003. PBDEs, comprising on average 42% BDE-209, were found in all samples. The levels were log-normally distributed with a geometric mean sigmaPBDE of 2000 ng g(-1), and a median of 1800 ng g(-1) dust. The levels in dust did not correlate with questionnaire information on house characteristics." "Assuming a mean dust ingestion rate and median dust and air concentrations, adults would be exposed to ca. 7.5 ng sigmaPBDE d(-1) via the dust ingestion pathway, which represents approximately 14% of total daily exposure when compared to diet (82%) and inhalation (4%). However, for toddlers the equivalent intakes would be 99 ng d(-1), representing 80% of their daily PBDE exposure. At high dust ingestion rates these values increase to 180 ng d(-1) (80% daily intake) for adults and 360 ng d(-1) (89% daily intake) for toddlers."

Wilford BH, Shoeib M, Harner T, Zhu J, Jones KC. Air Quality Research Branch, Meteorological Service of Canada, Environment Canada, 4905 Dufferin Street, Toronto, Ontario, Canada. Polybrominated diphenyl ethers in indoor dust in Ottawa, Canada: implications for sources and exposure. Environ Sci Technol. 2005 Sep 15;39(18):7027-35.

- as a result of long-range environmental transport

- information regarding bio-availability

"The consumer safety of farm-raised salmon could be improved by determining the transfer efficiency of hazardous pollutants from fish feed to the salmon. A controlled feeding trial for 30 weeks was carried out to investigate the transfer of polybrominated diphenyl ethers (PBDEs) in Atlantic salmon (Salmo salar). Using three feed concentrations, an average of 95% of the total PBDE content of feed accumulated in whole salmon. Skinned fillet accumulated 42-59% of the PBDE intake. Equal partitioning according to the lipid content of the tissue was demonstrated. The formation of less brominated PBDEs via preferential debromination from the meta-position was thought to explain the exceptional accumulation efficiencies of BDE 47, BDE 66, BDE 75, BDE 119 and BDE 183 that were either >100% or else increasing with the exposure dose. Monitoring of a larger number of PBDE congeners is recommended to verify the biotransformation routes. The PBDE concentration in salmon of different ages, fed on a known concentration of PBDEs in fish feed, could be predicted by using the accumulation efficiencies determined in this study."
Isosaari P, Lundebye AK, Ritchie G, Lie O, Kiviranta H, Vartiainen T. Department of Environmental Health, National Public Health Institute, PO Box 95, FI-70701 Kuopio, Finland. pirjo.isosaari@vtt.fi Dietary accumulation efficiencies and biotransformation of polybrominated diphenyl ethers in farmed Atlantic salmon (Salmo salar). Food Addit Contam. 2005 Sep;22(9):829-37.

(f) National and international risk evaluations, assessments or profiles and labelling information and hazard classifications, as available **(provide summary information and relevant references)**

European Union Risk Assessment Report, Diphenyl ether, octabromo derivative, Risk Assessment, Final Report 2003, France and United Kingdom, 2003

European Commission, DG Environment. Risk Profile and Summary Report for Octabromodiphenyl ether (octaBDE). Dossier prepared for the UNECE Convention on Long-range Transboundary Air Pollution, Protocol on Persistent Organic Pollutants. August 2005

(g) Status of the chemical under international conventions