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)

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Chemical name

pentabromobiphenyl ether (PentaBDE)
PBDE47 CAS = 40088-47-9 PBDE-99 CAS=32534-81-9

Date of submission

27 January 2006

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

(i) Production data:

Quantity

[1] 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)

[2] The brominated flame retardant industry association has estimated the total market demand for pentaBDE by region. In 2001, the association estimated demand in the Americas at 7100 metric tons; Europe at 150 metric tons; Asia at 150 metric tons; and the rest of the world at 100 tons for a total of 7500 metric tons. In 2002 and 2003, pentaBDE was no longer part of the market demand table. (Bromine Science and Environmental Forum, Estimated Market Demand for Brominated Flame Retardants, http://www.bsef.com/bromine/our_industry/index.php)

Location

[3] USA: Great Lakes Chemical Corporation, West Lafayette, Indiana. Great Lakes voluntarily stopped production of pentaBDE and octaBDE on 31 December 2004. (Great

Lakes Chemical Press Release, Great Lakes Chemical Corporation Completes Phase-out of Two Flame Retardants, 18 January 2005
http://www.e1.greatlakes.com/fr/addinfo/jsp/current_news_detail.jsp?contentfile=01182005_FR_phase_out.htm

[4] The brominated flame retardant industry association lists production sites for three primary producing companies but does not indicate which compounds are produced at which site: Albemarle (USA, France, Belgium, United Kingdom, Germany, Austria, Jordan, and Japan); Chemtura (USA and United Kingdom); and ICL Industrial Products (Israel, USA, Netherlands, and China). (Bromine Science and Environmental Forum, The brominated flame retardant industry, http://www.bsef.com/bromine/our_industry/index.php)

(ii) Uses

[5] PentaBDE is used in phenolic resins, PVC, polyurethane, rubber, paints and lacquers, and textiles at levels ranging from 5 – 30% by weight. Products containing these materials include wires and cables, furniture, carpets, mattresses, insulation panels, and bus, train, and airplane seats. (World Health Organization, Brominated diphenyl ethers, Environmental Heath Criteria, International Program on Chemical Safety, 1994)

(iii) Releases

Discharges

[6] PBDEs were measured in sediments and fish including plaice (Pleuronectes platessa), flounder (platichthys flesus) and dab (Limanda limanda) from several rivers and estuaries in the UK. The samples were collected near a PBDE production facility; several user industries; landfills probably receiving PBDE-containing wastes; and a control site (Tweed River). The pentaBDE concentrations in sediments at the control site or upstream of the PBDE production facility were less than 0.38 ng/g dry weight pentaBDE. Sediments collected downstream near the PBDE production facility contained 130 ng/g dry weight pentaBDE and levels downstream in the Tees estuary varied from 19 – 366 ng/g dry weight. Levels of octaPDE near the plant were nearly 400 ng/g dry weight while levels downstream in the Tees estuary varied from 29 – 1348 ng/g dry weight. The results indicated that the Great Lakes Chemical Company PBDE production plant is a major source of PBDEs even at the mouth of river 40 km away. (Allchin CR, Law RJ, Morris S. Polybrominated diphenylethers in sediments and biota downstream of potential sources in the UK. Environ Poll 105:197-207, 1999)

Losses

Landfills

[7] Leachates from landfills in Japan were analyzed for PBDEs and other brominated flame retardants. The sum of PBDE47, 99, and 100 ranged from not detected to 4000 pg/l in the raw leachate but were not detected in the treated leachate. A large amount of BFRs were observed in a site with a large amount of organics. The authors note that the leaching characteristics of PBDEs appeared to be augmented by dissolved humic matter in the leachate. (Osako M, Kim YJ, Sakai S. Research Center for Material Cycles and Waste Management, National Institute for Environmental Studies, 16-2 Onogawa, Tsukuba, Ibaraki 305-8506, Japan.

mosako@nies.go.jp Leaching of brominated flame retardants in leachate from landfills in Japan. Chemosphere 57:1571-1579, December 2004)

Sewage Sludge

[8] Upstream to downstream locations along the Penobscot River in Maine, USA were sampled for PBDEs. Concentrations of tetra and hepta PBDEs upstream varied from 800 – 1810 ng/g lipid while levels downstream varied from 5750 – 29,000 ng/g lipid. A putative PBDE source along the river was the Orono waste water treatment plant. PBDEs in the influent ranged from 4.2 – 4.3 ug/liter and in the effluent ranged from 0.31 – 0.9 ug/liter. Concentrations in the activated sludge varied from 1.32 – 3.80 ug/liter. The highest concentrations were found in the biosolids which varied from 2,320 – 3,530 ug/kg dry weight. Biosolids are commonly spread on agricultural land in the US and in some European countries. (Anderson TD, Macrae JD. Polybrominated diphenyl ethers in fish and wastewater samples from an area of the Penobscot River in Central Maine. Chemosphere August 3, 2005)

9 PBDEs were measured in effluent and sludge from a wastewater treatment plant by municipal authorities. Total PBDE concentrations in sludge varied from 61 – 1440 ug/kg dry wt and in discharged effluent concentrations varied from 4 – 29,000 pg/liter. PBDE47, 99, 209 were most abundant in sluge while PBDE47 and 99 were most abundant in treated effluent. The pentaBDE mixture comprised 88% of the total PBDEs in the effluent. The author estimates that PBDE discharge to San Francisco Estuary from effluent discharge is approximately 0.9 kg/year. (North KD. City of Palo Alto, Environmental Compliance Division, 2501 Embarcadero Way, Palo Alto, California 94303, USA. Tracking polybrominated diphenyl ether releases in a wastewater treatment plant effluent, Palo Alto, California. Environ Sci Technol 28: 4484-4488, September 2004)

[10] PBDEs were measured in sediment and infaunal invertebrates collected along a spatial gradient downstream from a wastewater treatment plant located on the Back River. Total PBDE concentrations in sediments ranged from 2,400 – 9,000 ng/g dry weight with PBDE209 representing more than 99% of the total. PBDE47 and 99 were the only congeners detected in all pore water samples at levels of 0.1 – 1.0 ng/liter with total PBDEs in pore water ranging from 0.2 – 1.8 ng/liter. (Klosterhaus SL, Stapleton HM, Baker JE. Chesapeake Biological Laboratory, University of Maryland Center for Environmental Science, Solomons, Maryland USA, National Institute for Standards and Technology, Gaithersburg, Maryland. Polybrominated diphenyl ethers (BDEs) in sediment, pore water, and infaunal invertebrates along a spatial gradient in an urban estuarine river receiving wastewater effluent in Baltimore, Maryland, USA. Brominated Diphenyl Ether (BDE) Residues in Canadian Human Fetal Liver and Placenta. Third International Workshop on Brominated Flame Retardants, University of Toronto, Ontario, Canada, June 6-9, 2004)

[11] The study investigated 36 sewage treatment plants; 22 urban plants and 12 industrial plants. The sewage represented effluents of paper mills, textile plants, metal working facilities, electronics manufacturing, and leather tanneries. PBDE47 and 99 levels ranged up to 15 ng/ liter in the effluents of urban plants and up to 6.4 ng/liter in the effluents of industrial plants. In sewage sludge, industrial samples ranged up to 65 ug/kg total PBDEs with PBDE47, 99, and 153 as major congeners. (Moche W, Thanner G. Federal Environment Agency of Austria, Vienna, Austria. Levels of PBDE in effluents and sludge from sewage treatment plants in Austria. Brominated Diphenyl Ether (BDE) Residues in Canadian Human Fetal Liver and Placenta. Third International Workshop on Brominated Flame Retardants, University of Toronto, Ontario, Canada, June 6-9, 2004)

[12] PentaBDE concentrations up to 3000 ug/kg dry weight were found in sewage sludge. "PBDE concentrations in US and Canadian sewage sludges appear to be at least 10-fold greater than European levels and may be a useful barometer of release." (Hale RC, Alaee M, Manchester-Neesvig JB, Stapleton HM, Ikonomou MG. Department of Environmental and Aquatic Animal Health, Virginia Institute of Marine Science, College of William and Mary, 1208 Greate Road, Gloucester Point, VA 23062, USA Polybrominated diphenyl ether flame retardants in the North American environment. Environ Int 29:771-779, September 2003)

(Hale RC, LaGuardia MJ, Harvery EP, Gaylor MO, Mainor TM, Duff WH. Flame retardants. Persistent pollutants in land-applied sludges. Nature 412:140-141, July 2001)

Rivers

[13] "From the data presented here, we can provide an estimate of the annual amount of PBDEs discharged into the Gulf of Mexico by the Mississippi River. Based on ÓPBDE concentrations at sites 25 and 26 from Figure 2 (~90 ng/g s.s.), the average annual suspended sediment concentration measured by the USGS (NASQAN) for the year 2002 at St. Francisville, LA (190 mg/L), and the annual discharge of water at Tarbert's Landing, MS obtained by integrating the average daily discharge over the year 2002 (4.7×10^{14} L/year),[6] we estimate that ~8 tons/year of BDEs were discharged into the Gulf of Mexico in 2002. This is comparable to a PCB load of 6.8 tons/year as determined by Rostad *et al.* in their 1989–1990 study." (Raff, J., Hites, R. School of Public and Environmental Affairs, Indiana University, Bloomington, Indiana 47405, USA Polybrominated diphenyl ethers in Mississippi River suspended sediment. Organohalogen Cpds. 66: 3722-3726, 2004)

Consumer Products

[14] Dust from 17 homes was analyzed for PBDEs. Total PBDE levels ranged from 1 – 399 ng/g with a geometric mean of 76 ng/g. PBDE209 was the dominant congener making up 85% of the total followed by PBDE99 making of 5% of the total and PBDE47 with 4.5% of the total. (Gevao B, Al-Bahloul M, Al-Ghadban AN, Al-Omair A, Ali L, Zafar J, Helaleh M. Department of Environmental Science, Kuwait Institute for Scientific Research, P.O. Box 24885, Safat 13109, Kuwait. House dust as a source of human exposure to polybrominated diphenyl ethers in Kuwait. Chemosphere, January 4, 2006)

[15] Stuffed toys for children were analyzed for PBDEs. PBDE47 was found in all toys and PBDE99 was found in almost all the toys. Levels of the two congeners usually ranged from 2 – 4 ppb though one toy contained 67,000 ppb PBDE47. The highest concentrations of PBDEs were found in the exterior fabric, not the stuffing. The authors conclude that, "The presence of these chemicals in stuffed toys may be a source of exposure for children." (Corbitt, C., and R. Falconer. Chatham College, Pittsburgh, PA, USA. Brominated flame retardants and organochlorine pesticides in children's stuffed toys. SETAC North America 26th Annual Meeting, Baltimore, Maryland, USA. Nov. 13-17, 2005)

[16] House dust from 68 homes in Ottawa, Canada was analyzed for PBDEs in 2002 – 2003. PBDEs were found in all samples with PBDE209 making up 42% of the total. Total PBDE levels averaged 2000 ng/g with a median of 1800 ng/g. The authors note that dust is far more significant as an exposure source for children and could constitute 80% - 89% of their daily intake. (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 39:7027-7035, September 2005)

[17] Four computer wipe samples and nine vacuum cleaner dust samples were analyzed for PBDES. All samples contained PBDEs with PBDE209 as the dominant congener in the computer wipe samples and in 7 of the 9 vacuum samples. (Schecter A, Papke O, Joseph JE, Tung KC. University of Texas, School of Public Health at Dallas, 6011 Hines Blvd., V8.112, Dallas, TX 75390, USA. Polybrominated diphenyl ethers (PBDEs) in U.S. computers and domestic carpet vacuuming: possible sources of human exposure. J Toxicol Environ Health A., 68:501-513, April 2005)

[18] A survey of 17 homes in the Washington, D.C. and Charleston, S.C. areas found high concentrations of PBDEs in household dust. Total PBDE concentrations varied from 780 – 30,100 ng/g dry mass. The dominant congeners were PBDE47, 99, and 209. Researchers analyzed both dust from floors and clothes dryer lint for 22 variants of commercial PBDEs and found PBDEs in every sample. Clothes dryer lint from five homes was analyzed for PBDEs and were present in all five samples ranging from 480 – 3080 ng/g dry mass. (Stapleton HM, Dodder NG, Offenberg JH, Schantz MM, Wise SA. National Institute of Standards and Technology, Gaithersburg, Maryland 20899, USA Polybrominated diphenyl ethers in house dust and clothes dryer lint. Environ Sci Technol 39:925-931, February 2005)

[19] Indoor air and dust was sampled in 120 homes and subjected to analysis for PBDEs and other suspected endocrine-disrupting compounds. BDE 47, BDE 99 and BDE 209 were found in the dust of all 89 homes sampled for PBDEs at concentrations up to 9.86, 22.5 and 3.40 micrograms/ gram, respectively. (Rudel RA, Camann DE, Spengler JD, Korn LR, Brody JG. Silent Spring Institute, Massachusetts, USA. Phthalates, alkylphenols, pesticides, polybrominated diphenyl ethers, and other endocrine-disrupting compounds in indoor air and dust. Environ Sci Technol 37:4543-4553, October 2003)

Emissions

Waste electrical and electronic equipment

[20] Analysis of waste electronic equipment in a Swiss recycling facility in 2003 revealed average concentrations of pentaBDE of 34 mg/kg. The authors point out that this is about seven times higher than the concentration present in Swiss electronic equipment in the 1990s. PBDEs were present in the fine dust fraction recovered in the off-gas purification system of the recycling plant. The authors point out the "high potential for BFR emissions from WEEE (waste electrical and electronic equipment) 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 39:8691-8699, November 2005)

(b) Hazard assessment for endpoints of concern, including consideration of toxicological interactions

involving multiple chemicals (provide summary information and relevant references)

Neurobehavioral effects

[21] Long-Evans rats administered the commercial pentaBDE mixture on post-natal day 6 were tested for visual discrimination and two sustained attention tasks. Exposed rats displayed deficits in learning but not sustained attention. However, exposed rats were subsensitive to a drug challenge with the muscarinic antagonist, scopolamine, suggesting alternations in the cholinergic modulation of sustained attention. (Dufault C, Poles G, Driscoll LL. Department of Psychology, The Colorado College, Colorado Springs, Colorado 80903, USA Brief postnatal PBDE exposure alters learning and the cholinergic modulation of attention in rats. Toxicol Sci 88:172-180, November 2005)

[22] PBDE99 caused developmental neurotoxic effects such as hyperactivity in neonatal C57/Bl mice of both sexes when exposed on day 10 to 0.4, 0.8, 4.0, 8.0, or 16 mg PBDE99/kg body weight. Changes in spontaneous behavior were dose-response and time-response related for both sexes. The effects for PBDE99 are similar to effects seen with PBDE47, 153, 209 and for certain PCBs in male NMR1 mice. (Viberg H, Fredriksson A, Eriksson P. Department of Environmental Toxicology, Uppsala University, Norbyvagen 18A, S-75236 Uppsala, Sweden. Henrik.Viberg@ebc.uu.se Investigations of strain and/or gender differences in developmental neurotoxic effects of polybrominated diphenyl ethers in mice. Toxicol Sci 31:344-353, October 2004)

[23] PBDE99 produced several behavioral alternations with some of them different from PCBs which were used a positive control. CD-1 Swiss female mice were exposed to 0.6, 6, and 30 mg/kg day PBDE99 from gestational day 6 to postnatal day 21. The medium dose affected litter viability. At 30 mg/kg, the climbing response was delayed. Other effects included alterations in the homing test; spending more time in the center of the arena; and hypoactivity. (Branchi I, Alleva E, Costa LG. Department of Pharmacology of Natural Substances and General Physiology, University of Rome La Sapienza, Italy. branchi@iss.it Effects of perinatal exposure to a polybrominated diphenyl ether (PBDE 99) on mouse neurobehavioural development. Neurotoxicology 23:375-384, September 2002)

[24] Neonatal NMRI male mice were exposed 8 mg pentaBDE on day 3, 10, or 19 and spontaneous motor behavior was observed in 4-month old mice. Mice exposed on days 3 or 10 showed significantly impaired behavior whereas no effect was observed in mice exposed on day 19. Radioactive pentaBDE was administered to determine if it could be detected in the brain. Radioactivity in the brains of mice was not higher in mice exposed on day 3 or 10 when compared to exposure on day 19. The authors conclude that the behavioral disturbances caused by pentaBDE are induced during a defined critical period of neonatal brain development. (Eriksson P. Viberg H, Jakobsson E, Orn U, Fredirksson A, Department of Environmental Toxicology, Uppsala University, Norbyvagen 18A, SE-75236 Uppsala, Sweden. Per.eiksson@ebc.uu.se A brominated flame retardant 2,2',4,4',5-pentabromodiphenyl ether: uptake, retention, and induction of neurobehavioral alterations in mice during a critical phase of neonatal brain development. Toxicol Sci 67:98-103, May 2002)

[25] PBDE47 and 99 were administered to 10 day old NMRI male mice at 0.7 mg/kg and 10.5 mg/kg for PBDE47 and 0.8 mg/kg and 12 mg/kg for PBDE 99. Both congeners

caused permanent aberrations in spontaneous behavior in 2 and 4 month old animals in a dose-response related manner. Neonatal exposure to PBDE99 affected learning and memory functions in adult animals. The authors note that these developmental defects have been detected previously following exposure to PCBs. (Eriksson P, Jakobsson F, Fredriksson A. Department of Environmental Toxicology, Uppsala University, Norbyvagen 18A, SE-75236 Uppsala, Sweden. Per.eiksson@ebc.uu.se Brominated flame retardants: a novel class of developmental neurotoxicants in our environment? Environ Health Perspect 109:903-908, September 2001)

Neural signaling effects

[26] Cerebellar granule neuronal cultures were exposed to individual PBDE congeners of the commercial pentaBDE mixture. On a nanomole basis, accumulation of PBDE47, 99, and 153 was linear with time. Accumulation was linear with concentration for PBDE47 but not PBDE99 and 153. PBDE accumulation correlated with protein kinase C translocation as seen with other organohalogens including PCBs. All three congeners increased 3H-phorbol ester binding at levels as low as 10 microM and at levels where no cytotoxicity was observed. These effects were similar to those observed with PCB congeners. (Kodavanti PR, Ward TR, Ludewig G, Robertson LW, Birnbaum LS. Cellular and Molecular Toxicology Branch, Neurotoxicology and Experimental Toxicology Division, NHEERL, ORD, US Environmental Protection Agency, Research Triangle Park, North Carolina 27711, USA. kodavanti.prasada@epa.gov Polybrominated diphenyl ether (PBDE) effects in rat neuronal cultures: 14C-PBDE accumulation, biological effects, and structure-activity relationships. Toxicol Sci 88:181-192, November 2005)

[27] The commercial pentaBDE mixture was used to test the effect on intracellular signaling mechanisms Protein kinase C translocation was tested with (3)H phorbol ester binding in rat cerebellar granule cells and calcium buffering was determined using (45)C(2+) uptake by microsomes and mitochondria isolated from adult male rat brain (frontal cortex, cerebellum, and hippocampus). PentaBDE increased Protein kinase C translocation and inhibited (45)C(2+) uptake by microsomes and mitochondia in a concentration-dependent manner in a similar manner as PCBs. In fact, the effect of Aroclor 1254 and pentaBDE on mitochondrial (45)C(2+) uptake was equal. The authors indicate that PBDEs peturb intracellular signaling mechanisms in rat brain. (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 85:952-962, June 2005)

[28] PBDE99 caused the translocation of the three Protein kinase C isozymes in 132-1N1 human astrocytoma cells while Aroclor 1254 only affected two of the isozymes. PBDE99 (but not Aroclor 1254) induced apoptosis in astrocytoma cells via a p53 dependent mechanism. The authors suggest that PBDE99 and Aroclor 1254 exert differential cytotoxic effects on human astroglial cells. (Madia F, Giordano G, Fattori V, Vitalone A, Branchi I, Capone F, Costa LG. Department of Pharmacology of Natural Substances and General Physiology, University of Rome La Sapienza, Italy. Differential in vitro neurotoxicity of the flame retardant PBDE-99 and of the PCB Aroclor 1254 in human astrocytoma cells. Toxciol Lett 154:11-21, December 2004)

[29] This study indicates that the developing cholinergic system may be sensitive to PBDEs. PBD99-treated neonatal male NMRI mice showed a hypoactive response to nicotine, similar to that observed in neonatal exposure to PCBs and nicotine. (Viberg H, Fredirksson A, Eriksson P. Department of Environmental Toxicology, Uppsala University, Norbyvagen 18A, SE-75236 Uppsala, Sweden. Henrik.viberg@ebc.uu.se Neonatal exposure to the brominated flame retardant 2,2',4,4',5-pentabromodiphenyl ether causes altered susceptibility in the cholinergic transmitter system in the adult mouse. Toxicol Sci 67:104-107, May 2002)

Reproductive/developmental effects

[30] In utero exposure to a single dose of 60 or 300 ug PBDE99/kg body weight in Wistar rat dams on gestation day 6 disrupted neurobehavioral development and caused permanent effects on the reproductive system of male offspring. Spermatogenesis was permanently impaired by both reduced sperm and spermatid counts. Assessment of locomotor activity on postnatal days 36 and 71 demonstrated hyperactivity in the offspring. The authors point out that the doses of PBDE99 are relevant to human exposure levels since they are 6 and 29 times higher than the highest level reported in human breast adipose tissue. The low dose used in this study is the lowest dose of PBDE reported to have an in vivo toxic effect in rodents. (Kuriyama SN, Talsness CE, Grote K, Chahoud I. Institute of Clinical Pharmacology and Toxicology, Department of Toxicology, Charite University Medical School Berlin, Campus Benjamin Franklin, Berlin, Germany Developmental exposure to low dose PBDE99: effects on male fertility and neurobehavior in rat offspring. Environ Health Perspect 113:149-154, February 2005)

[31] The commercial pentaBDE mixture was tested in a female and male pubertal protocol test that reveals the presence of thyroid active chemicals. Male and female Wistar rats were gavaged daily with 0, 3, 30, or 60 mg/kg pentaBDE. In females, doses of 30 or 60 mg/kg significantly deceased serum T4 in rats exposed for 5 or 21 days. In males, doses of 3, 30, or 60 mg/kg significantly decreased serum T4 in rats exposed for 30 days. In addition, serum T3 was decreased and TSH elevated in male rats exposed for 31 days to 30 or 60 mg/kg pentaBDE. Decreased colloid area and increased follicular cell heights indicating a hypothyroid state occurred males and females exposed to 60 mg/kg for 21 and 30 days respectively. In males, the 60 mg/kg dose reduced seminal vesicle and ventral prostate weights. In females, this dose significantly delayed preputial separation and caused a significant delay in the age of the vaginal opening. (Stoker TE, Laws SC, Crofton KM, Hedge JM, Ferrell JM, Cooper RL. Reproductive Toxicology Division, National Health and Environmental Effects Research Laboratory, U.S. Environmental Protection Agency, Research Triangle Park, North Carolina 27711, USA. stoker.tammy@epa.gov Assessment of DE-71, a commercial polybrominated diphenyl ether (PBDE) mixture, in the EDSP male and female pubertal protocols. Toxicol Sci 78:144-155, March 2005)

Hormone effects

[32] Congeners of the PentaBDE commercial mixture were injected into kestrel eggs (Falco sparverius) at levels similar to those found in gull eggs (1500 ng/g) and later fed to nestlings. PBDE47 was associated with lower plasma thyroxine (T4) and lowered hepatic retinol concentrations. (Fernie KJ, Shutt JL, Mayne G, Hoffman D, Letcher RJ, Drouillard KG, Ritchie IJ. Canadian Wildlife Service, Burlington, Ontario, Canada, L7R 4A6 Patuxent Wildlife Research Center, Laurel, Maryland; Great Lakes Institute for Environmental Research, University of Windsor, Windsor, Ontario, Canada, N9B 3P4 Avian Science and Conservation Centre, McGill University, Ste Anne de

Bellevue, Quebec, Canada, H9X 3V9. Exposure to polybrominated diphenyl ethers (PBDEs): Changes in thyroid, vitamin A, glutathione homeostasis, and oxidative stress in American kestrels (Falco sparverius) Toxicol Sci 88:375-383, December 2005)

[33] The commercial pentaBDE mixture, DE71, was tested for anti-androgenic effects. A dose-dependent delay in preputial segregation was observed in male Wistar rats at 60 and 120 mg/kg/day administered for four and five days. Suppression of ventral prostrate and the growth of seminal vesicles were observed at both concentrations. Doses of 30 – 240 mg/kg pentaBDE administered in the immature rat Hershberger assay decreased ventral prostrate and seminal vesicle weight. The pentaBDE mixture competitively inhibited human androgen receptor binding in a transcriptional activation assay with IC50s of approximately 5 microM. The authors hypothesize that the delay in puberty in male rats exposed to pentaBDE was likely due to inhibition of androgen receptor binding. (Stoker TE, Cooper RL, Lambright CS, Wilson VS, Furr J, Gray LE. MD-72, Endocrinology Branch, Reproductive Toxicology Division, National Health and Environmental Effects Research Laboratory, Office of Research and Development, United States EPA, Research Triangle Park, NC 27711, USA. stoker.tammy@epa.gov In vivo and in vitro anti-androgenic effects of DE71, a commercial polybrominated diphenyl ether (PBDE) mixture. MD-72, Endocrinology Branch, Reproductive Toxicology Division, National Health and Environmental Effects Research Laboratory, Office of Research and Development, United States EPA, Research Triangle Park, NC 27711, USA. stoker.tammy@epa.gov Toxicol Appl Pharmacol 22:78-88, August 2005)

[34] "Whereas transthyretin (TTR) is the major thyroid hormone binding protein in rats, TBG is the main binding protein in humans and most other mammals. However, although TTR is not the main transport protein in human serum, it is the principal protein involved in transport of T4 to the brain in both rats and man. Therefore, without specific evidence that rats are more sensitive to PBDEs than humans, and considering the importance of TTR for the transport of thyroid hormones in the human brain, it is misleading to assume that PBDEs are unlikely to affect thyroid function in humans, or that humans are less sensitive to these effects than rats." (Agency for Toxic Substances and Disease Registry, USA Department of Health and Human Services. Toxicological profile for polybrominated biphenyls and polybrominated diphenyl ethers. September 2004)

[35] PBDE47 was administered to female Sprague-Dawley rats at 1.0, 6.0, 18 mg/kg day. The results showed a decrease in thyroid hormone that corresponded to a decrease in ex vivo binding of T4 to the plasma thyroid hormone transporter transthyretin. The study showed synergistic effects in mixtures of PBDE47 and Witaclor 171P (commercial chlorinated paraffin mixture). (Hallgren S, Darnerud PO. Department of Pharmaceutical Biosciences, Division of Toxicology, Uppsala University, P.O. Box 594, Uppsala, Sweden Polybrominated diphenyl ethers (PBDEs), polychlorinated biphenyls (PCBs) and chlorinated paraffins (CPs) in rats-testing interactions and mechanisms for thyroid hormone effects. Toxicology 177:227-243, August 2002)

[36] The commercial pentaBDE mixture was administered to primiparous Long-Evans rats orally at 0, 1, 10, and 30 mg/kg day from gestation day 6 to postnatal day 21. There were no significant effects on maternal body weight gain, litter size, sex ratio, offspring viability, T3 concentrations, or growth. Serum T4 was reduced in a dose-dependent manner in fetuses by at least 15% (gestation day 20) and in offspring (postnatal day 4 and 14) by up to 64%. Control levels returned at postnatal day 36. Increased liver to body weight ratios were observed which were consistent with induction of hepatic microsomal

ethoxy- and pentoxy-resorufin-O-deethylase (EROD and PROD) (up to 95-fold and 26-fold) or uridine diphosphoglucuronosyl transferase (UDPGT) (up to 4.7-fold). Both EROD and UDPGT induction was much greater in offspring compared to dams. The authors conclude that pentaBDE is an endocrine disrupter in rats during development. (Zhou T, Taylor MM, DeVito MJ, Crofton KM. Curriculum in Toxicology, University of North Carolina, Chapel Hill, North Carolina, USA. Developmental exposure to brominated diphenyl ethers results in thyroid hormone disruption. Toxicol 66:105-116, March 2002)

[37] Female C57BL/6 mice were exposed to the commercial pentaBDE mixture orally at 0, 0.8, 4.0, 20, 100, or 500 mg/kg or subchronic daily doses of 0, 250, 500, or 1000 mg/kg over 14 days. Total serum T4 concentrations were significantly lower in mice treated acutely except for those at the 100 mg/kg dose. Subchronic exposure decreased total and free T4 in a dose-dependent manner. (Fowles JR, Fairbrother A, Baecher-Steppan L, Kerkvliet NL. Toxicology Program, Oregon State University, Corvallis 97331. Immunologic and endocrine effects of the flame-retardant pentabromodiphenyl ether (DE-71) in C57BL/6J mice. Toxicology 86:49-61, January 1994

Immunological effects

[38] Pathological exams and contaminant analysis were performed on 61 by-caught and stranded harbor porpoises. Thymic atrophy and splenic depletion were significantly correlated with increased PCB and PBDE levels. The authors point out that lymphoid depletion is also associated with impaired health status and hypothesize that contaminant-induced immunosuppression may contribute to disease susceptibility in harbour porpoises. (Beineke A, Siebert U, McLachlan M, Bruhn R, Thron K, Failing K, Muller G, Baumgartner W. Institut fur Pathologie, Tierarztliche Hochschule Hannover, 30559 Hannover, Germany. andreas.beineke@tiho-hannover.de Investigations of the potential influence of environmental contaminants on the thymus and spleen of harbor porpoises (Phoceona phoceona). Environ Sci Technol 39:3933-3938, June 2005)

[39] Captive nestling kestrels were exposed to pentaBDE at ~15.6 ng/g body weight/day to mimic exposure observed in Great Lakes birds. After 29 days body burden levels were 86 +/- 29 ng/g ww. Exposed birds had greater PHA response through T-cell-mediated immunity which was negatively associated with increasing PBDE47 concentration. Structural changes were observed in the spleen, bursa, and thymus. (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 138:485:493, December 2005)

Liver toxicity

[40] "The hepatotoxic potential of lower brominated PBDE mixtures is well-documented in animals by oral exposure. The spectrum of observed hepatic effects includes microsomal enzyme induction, liver enlargement, and degenerative histopathologic alterations that progress to tumors. Repeated dietary exposure to PBDEs typically caused liver enlargement with or without degenerative changes, and effects were generally dose-related in incidence and severity, more frequent and pronounced in males than females, and more severe with octaBDE and pentaBDE than decaBDE. For example, subchronic oral studies in rats showed that commercial pentaBDE mixtures were hepatotoxic at

doses ⩽10 mg/kg/day. Increased liver weight and hepatocellular enlargement with vacuolation occurred in rats exposed to commercial pentaBDE doses as low as 2–9 mg/kg/day for 4–13 weeks. Increased incidences of degeneration and necrosis of individual hepatocytes were observed 24 weeks following exposure to ⩾2 mg/kg/day of commercial pentaBDE for 90 days in rats… Based on the evidence in animals, lower brominated PBDEs are potentially hepatotoxic in humans." (Agency for Toxic Substances and Disease Registry, USA Department of Health and Human Services. Toxicological profile for polybrominated biphenyls and polybrominated diphenyl ethers. September 2004)

[41] PentaBDE mixture at 0, 0.1, and 1 microM was incubated beginning on day 3 with cultured carp (Cyprinus carpio) hepatocytes for eight days to test for effects on EROD activity. PBDE47 displayed the strongest inhibition of EROD activity (6% of the TCDD control value). EROD is part of the cytochrome P450 (CYP1A) microsomal oxygenase subfamily and is used as a biomarker for exposure to pollutants. (Kuiper RV, Bergman A, Vos JG, van den Berg M. Institute for Risk Assessment Sciences (IRAS), Utrecht University, PO Box 80176, 3508 TD Utrecht, The Netherlands. r.v.kuiper@vet.uu.nl Some polybrominated diphenyl ether (PBDE) flame retardants with wide environmental distribution inhibit TCDD-induced EROD activity in primary cultured carp (Cyprinus carpio) hepatocytes. Aquat Toxicol 68:129-139, June 2004)

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

Chemical/physical properties

Please see POPRC1-INF-5-b

Persistence

Please see POPRC1-INF-5-b

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

[42] PBDE47 and PBDE99 were both among the dominant congeners found in particulates in the oceanic atmosphere from the Bohai Sea to the Arctic. The sum of 11 congeners ranged from 2.25 – 198.9 pg/m3 with a mean of 58.3 pg/m3. PBDE47, 99, 100, and 209 were the dominant congeners in all samples. PBDE levels decreased from the mid- to high-latitudinal regions of the North Pacific. The authors hypothesize that this is due to dilution, deposition, and decomposition of PBDEs during long range transport of air masses. They point out that no geographical pattern of PBDE distribution was observed in the Arctic and suggest that unstable air circulation and air mixing is the cause. The authors note that PBDE congeners are higher in the Arctic (17.3 pg/m3) than in the North Pacific (12.8 pg/m3) and indicate that this is consistent with global fractionation. (Wang XM, Bing X, Mai BX, Xie ZQ, Xiang CH, Sun LG, Sheng GY, Fu JM, Zeng EY. State Key Laboratory of Organic Geochemistry, Guangzhou Institute of Geochemistry, Chinese Academy of Sciences, Guangzhou 510640, China. wangxm@gig.ac.cn Polybrominated diphenyl ethers in airborne particulates collected during a research expedition from the Bohai Sea to the Arctic. Environ Sci Technol 15, 39: 7803-7809. 2005)

[43] "Empirical and predicted data indicate that all PBDEs under consideration are highly persistent and are subject to long-range transport and each satisfies the requirements for persistence as defined by the CEPA 1999 Persistence and Bioaccumulation Regulations. Although considered persistent, evidence suggests that PBDEs are susceptible to some degree of metabolic transformation and photodegradation. Studies have shown the transformation of higher brominated PBDEs (e.g., hepta– to decaBDEs) to lower brominated congeners (e.g., congeners of tetraBDE, pentaBDE and hexaBDE) which are associated with high levels of bioaccumulation." (Pasternak J, Suffredine L, Taylor. Environment Canada, The Draft Environmental Screening Assessment of Polybrominated Diphenyl Ethers in Canada. Third International Workshop on Brominated Flame Retardants, University of Toronto, Ontario, Canada, June 6-9, 2004)

[44] The air surface exchange of PBDEs was studied in air and leaf litter samples collected over a three day period in rural Ontario, Canada in the early spring prior to bud burst. Total PBDE concentration in air ranged from 88 – 1250 pg/m3. PBDE47, 17, and 28 dominated the congeners measured. Slopes of Clausius-Clapeyron plots indicate that PBDEs and PCBs are experiencing active air-surface exchange. Forty air samples were collected at 24 hour intervals to determine the effect of bud burst.Total PBDE concentrations varied from 10 – 230 pg/m3 and were dominated by PBDE47, 17, and 28. The authors hypothesize that an early spring pulse created the high initial PBDE concentrations in air that resulted from liberation of PBDEs from melting snow. (Gouin T, Thomas GO, Cousins I, Barber J, Mackay D, Jones KC Canadian Environmental Modelling Centre, Trent University, Peterborough, Ontario. Air-surface exchange of polybrominated diphenyl ethers and polychlorinated biphenyls. Environ Sci Technol 26:1426-1434, April 2002)

Formation of other POPs

[45] "It is important to note that agricultural and farmland application of sewage sludge is widely practiced in the US. In some European countries (as well as in the US), sewage sludge may be burned in waste incinerators. This practice can lead to the formation and release of brominated dioxins and furans into the environment." (Fardin O. Flame retardants: Polybrominated diphenyl ethers (PBDEs). Minnesota Pollution Control Agency, State of Minnesota, USA February 17, 2005)

[46] "Pyrolysis and extreme heating can cause all PBDEs to form brominated dibenzo–*p*–dioxins and dibenzofurans. These transformation products are considered to be brominated analogues of the Government of Canada Toxic Substances Management Policy (TSMP) Track 1 substances polychlorinated dibenzo–*p*–dioxins and dibenzofurans. (Pasternak J, Suffredine L, Taylor. Environment Canada, The Draft Environmental Screening Assessment of Polybrominated Diphenyl Ethers in Canada. Third International Workshop on Brominated Flame Retardants, University of Toronto, Ontario, Canada, June 6-9, 2004)

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

Please see POPRC1-INF-5-b

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

Human Breast Milk

[47] This is the first large scale study of current PBDE levels in breast milk in Japan. PBDE47 was found in 99% of 105 Japanese breast milk samples and it was the most abundant congener detected of the six that were measured; PBDE28, 47, 99, 100, 153, and 154. Total PBDE levels ranged from 0.01 ng/g lipid - 23 ng/g lipid with a geometric mean of 1.34 ng/g lipid. PBDE47 represented 59% of the total congeners detected and was presented at geometric mean levels of 0.66 ng/g lipid. Total PBDE levels were higher in northern Japan than in other areas. (Eslami B, Koizumi A, Ohta S, Inoue K, Aozasa O, Harada K, Yoshinaga T, Date C, Fujii S, Fujimine Y, Hachiya N, Hirosawa I, Koda S, Kusaka Y, Murata K, Nakatsuka H, Omae K, Saito N, Shimbo S, Takenaka K, TAkeshita T, Todoriki H, Wada Y, Watanabe T, Ikeda M. Department of Health and Environmental Sciences, Kyoto University Graduate School of Medicine, Kyoto 606-8501, Japan Large scale evaluation of the current level of polybrominated diphenyl ethers (PBDEs) in breast milk from 13 regions of Japan. Chemosphere, Nov 21, 2005)

[48] Human milk from the Faroe Islands was sampled in 1987, 1994/5 and 1999. Pooled samples of 10 mothers were analyzed for PBDEs and PCBs along with 10 individual samples from 1999. A steep increase in PBDE concentrations was observed between 1987 and 1999. Total PBDE concentrations were 1.9 – 2.1 ng/g lipid in 1987; 4.0 – 4.2 ng/g lipid in 1994/1995; and 8.0 – 8.4 ng/g lipid in 1999. PBDE47 increased from 0.37 – 0.40 ng/g lipid in 1987 to 1.6-1.7 ng/g lipid in 1999. PBDE99 increased from 0.15 – 0.17 ng/g lipid in 1987 to 0.91 – 0.94 ng/g lipid in 1999. Unlike typical congener patterns, the samples showed that PBDE153 was the dominant congener instead of PBDE47. The authors note that the Faroe Islands are located far from industrial sources of PBDEs and consume a seafood-based diet including pilot whale meat and blubber and seabirds. (Fangstrom B, Strid A, Grandjean P, Weihe P, Bergman A. A retrospective study of PBDEs and PCBs in human milk from the Faroe Islands. Environmental Health: A global access science source 4:12, July 2005)

[49] Breast milk samples from 54 mothers from southeast England (London) and 27 from northeast England (Lancaster) were tested for PBDEs, PCBs, and other organochlorines. PBDE47 was the most abundant PBDE congener with sigma PBDE levels ranging from 0.3 – 69 ng/g lipid. (Kalantzi OI, Martin FL, Thomas GO, Alcock RE, Tang HR, Drury SC, Carmichael PL, Nicholson JK, Jones KC. Department of Environmental Science, Institute of Environmental and Natural Sciences, Lancaster University, Lancaster, United Kingdom. Different levels of polybrominated diphenyl ethers (PBDEs) and chlorinated compounds in breast milk from two U.K. Regions. Environ Health Perspect 112:1085:1091, July 2004)

[50] 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. PBDE47 concentrations varied from 2.9 – 271 ng/g lipid with a median of 18.4 ng/g lipid; and a mean of 40.8 ng/g lipid. PBDE99 varied from 0.7 ng/g lipid to 110 ng/g lipid with a median of 5.7 ng/g lipid and a mean of 14 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 111:1723-1729, November 2003)

[51] Breast milk collected from 93 mothers in 1996 – 1999 from Uppasala, Sweden was analyzed for the sum of PBDE47, 99, 100, 153, and 154. The mean sigma concentration was 4.0 ng/g lipid. PBDE47 represented 59% of the mean concentration of PBDEs. (Lind Y, Darnerud PO, Atuma S, Aune M, Becker W, Bjerselius R, Cnattingius S, Glynn A. Swedish National Food Administration, PO Box 622, SE-751 26 Uppsala, Sweden. Polybrominated diphenyl ethers in breast milk from Uppsala County, Sweden. Environ Research 93:186-194, October 2003)

[52] The time trend of 16 PBDE congeners including PBDE47 and 99 was investigated in pooled breast milk samples of women living in Osaka, Japan. Sigma PBDE concentrations increased from 1973 (<0.1 ng/g lipid) to 1988 (1.64 ng/g lipid) and remained low. Another measurement in 13 samples collected in 1999 showed sigma concentrations of 0.56 – 3.07 ng/g lipid except for a single sample that contained 291 ng/g lipid. (Akutsu K, Kitagawa M, Nakazawa H, Makino T, Iwazaki K, Oda H, Hori S. Division of Food Chemistry, Osaka Prefectural Institute of Public Health, 1-3-69, Nakamichi, Higashinari-ku, Osaka 537-0025, Japan. akutu@iph.pref.osaka.jp Time-trend (1973-2000) of polybrominated diphenyl ethers in Japanese mother's milk. Chemosphere 53:645-554, November 2003)

[53] Pooled samples of breast milk from Swedish women were collected at eight time periods between 1972 and 1997 and analyzed for PBDEs. PBDE47 was the most abundant congener of the eight that were identified. Levels of total PBDEs increased from 0.07 ng/g lipid in 1972 to 4.02 ng/g lipid in 1997 (57-fold increase). (Meironyte D, Noren K, Bergman A. Department of Medical Biochemistry and Biophysics, Karolinska Institute, Stockholm, Sweden. Daiva.meironyte@mbb.ki.se Analysis of polybrominated diphenyl ethers in Swedish human milk. A time-related trend study, 1972 – 1997. J Toxicol Environ Health A 58:329-341, November 1999)

Human Fat

[54] Preliminary data from Brazil indicated that PBDE 47 was the major congener in human adipose tissue collected from Porto Alegre in 2004-2005. Total PBDE concentrations ranged from 0.73 to 3.69 ng/g lipid, with a mean of 1.89 ng/g lipid. (Kalantzi, OI, Brown, FR, Erdmann C, Caleffi M, Goth-Goldstein R, Petreas M. Polybrominated diphenyl ethers (PBDEs) in human breast adipose tissue samples from Brazil. *Organohalogen Compds*, 67, 479-481, 2005)

[55] PBDEs were measured in 53 human adipose tissue samples from 31 men and 22 women with a mean age of 53 years. Total PBDEs included congeners PBDE28, 47, 99, 100, 153, 154, and 183. Total PBDE levels ranged from 1.23 – 57.2 ng/g lipid and were similar to levels observed in other European countries. (Naert C, Piette M, Bruneel N, VanPeteghem C. Laboratory of Food Analysis, Faculty of Pharmaceutical Sciences, Ghent University, Harelbekestraat 72, Ghent, 9000, Belgium. Occurrence of Polychlorinated Biphenyls and Polybrominated Diphenyl Ethers in Belgian Human Adipose Tissue Samples. Arch Environ Contam Toxicol, January 2, 2006)

[56] PBDE47 was the major congener detected in a study of 52 human adipose samples collected in New York, USA during 2003-2004 followed by PBDE99. Concentrations of total PBDEs (di – hexaBDE congeners) varied from 17 – 9630 ng/g lipid wt with a mean concentration of 399 ng/g lipid wt; about 10- to 100-times higher than those reported for European countries and similar to concentrations observed for PCBs. PBDE

concentrations did not increase with age. (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. Enviromental Sci Technol 39:5177:5182, July 2005)

[57] Human adipose tissue samples collected in Tokyo, Japan in 1970 and 2000 contained 7 PBDEs including PBDE47 and 99. Median concentrations of total PBDEs significantly increased from 29.2 to 1288 pg/g lipid during the 30 year time period. PBDE47 represented 56% and 36% of the total in samples collected in 1970 and 2000 respectively. **(**Choi JW, Fujimaki TS, Kitamura K, Hashimoto S, Ito H, Suzuki N, Sakai S, Morita M. National Institute for Environmental Studies, 16-2 Onogawa, Tsukuba-Shi, Ibaraki 305-8506, Japan choi.jae.won@nies.go.jp Polybrominated dibenzo-p-dioxins, dibenzofurans, and diphenyl ethers in Japanese human adipose tissue. Environ Sci Technol 37:817-821, March 2003)

[58] Archived adipose tissue from 11 harbor seals (Phoca vitulina Richardsi) and 23 women from California were analyzed for PBDEs. The women contained PBDE47, 153, 154, 99, and 100 at average levels of 86 ng/g fat. Levels PBDEs in harbor seal blubber were in the low ng/g fat – low ug/g fat range. PBDE47 was the highest among all congeners in all samples. The current levels in seals are among the highest reported for this species and represent dramatic increases over the past decade. (She J, Petreas M, Winkler J, Visita P, McKinney M, Kopec D. Hazardous Materials Laboratory, California Department of Toxic Substances Control, Berkeley, 94704, USA jshe@dtsc.ca.gov PBDEs in the San Francisco Bay Area: measurements in harbor seal blubber and human breast adipose tissue. Chemosphere 46:697:707, February 2002)

Human Blood

[59] Urban anglers from New York and New Jersey, USA, were tested for PBDEs. Congeners found in the highest concentrations were PBDE47, 153, and 99. Anglers who consumed local fish had high levels of PBDEs than those who did not, but the difference was not statistically significant. (Morland KB, Landrigan PJ, Sjodin A, Gobeille AK, Jones RS, McGahee EE, Needham LL, Paterson DG Jr. Department of Community and Preventive Medicine, Mount Sinai School of Medicine, New York, New York, USA; and National Center for Environmental Health, Centers for Disease Control and Prevention, Atlanta, Georgia, USA. Body burdens of polybrominated diphenyl ethers among urban anglers. Environ Health Perspect 113:1689-1692, August 2005)

[60] PBDE47, 99, 100, 153, 154, and 183 were found in analyses of human blood serum from 154 volunteers in the UK. Overall concentrations of PBDEs were similar to those reported in Sweden in 2002. (Thomas GO, Wilkinson M, Hodson S, Jones KC. Department of Environmental Sciences, IENS, Lancaster University, Lancaster LA1 4YQ, UK Organohalogen chemicals in human blood from the United Kingdom. Environ Pollut, October 14, 2005)

[61] Concentrations of PBDE47 in the serum of contemporary California, USA women (n=50) ranged from 5 – 510 ng/g lipid; with a median of 16.5 ng/g lipid. The authors note that these levels are 3 – 10 times higher than those reported from Europe. Concentrations of PBDE47 in breast adipose tissue (n=32) varied from 5.2 – 196 ng/g lipid with a median of 16.5 ng/g lipid. PBDEs were not measurable in any of the 420 archived serum samples from the 1960s. Since PBDE47 concentrations did not increase with age or together with PCB153 the authors suggest that routes of exposure other than diet are probably occurring. (Petreas M, She J, Brown FR, Winkler J, Windham G, Rogers F, Zhao G, Bhatia

R, Charles MJ. Hazardous Materials Laboratory, Department of Toxic Substances Control, California Environmental Protection Agency, Berkeley 94704, USA. mpetreas@dtsc.ca.gov High body burdens of 2,2',4,4'-tetrabromodiphenyl ether (BDE-47) in California women. Environ Health Perspect 111:1175-1179, July 2003)

Animal

[62] PBDEs, HBCDs, cyclododeca-1,5,9-triene, and mercury were measured in seabird eggs from northern Norway and Svalbard. PBDE47 was the most abundant congener constituting 35 – 77% of the total PBDEs. Levels of PBDE47 and 99 increased (Knudsen LB, Gabrielsen GW, Verreault J, Barrett R, Skare JU, Polder A, Lie E. Temporal trends of brominated flame retardants, cyclododeca-1,5,9-triene, and mercury in eggs of four seabird species from Northern Norway and Svalbard, Norwegian Polar Institute, Tromso University Museum, National Veterinary Institute of Norway, Norwegian School of Veterinary Science. SPFO-Report 942/2005, December 2005)

[63] PBDE47 and 99 were measured in un-hatched eggs from six predatory bird species in Norway including peregrine falcon, golden eagle, osprey, merlin, goshawk, and white-tailed sea eagle. PBDE47, 99 and 153 were the dominating congeners. Eggs of the white tailed eagle contained up to 800 ng/g wet weight total PBDEs (median 184 ng/g wet weight. Peregrine falcon and osprey eggs contained 155 and 105 ng/g wet weight total PBDEs respectively. Golden eagle eggs contained 3 ng/g wet weight total PBDEs. (Herzke D, Berger U, Kallenborn R, Nygard T, Vetter W. Norwegian Institute for Air Research, NO-9296 Tromso and NO-2027 Kjeller, Norway. dorte.herzke@nilu.no Brominated flame retardants and other organobromines in Norwegian predatory bird eggs. Chemosphere 61: 441-449. October 2005)

[64] Free-range chicken eggs were sampled at 11 sites located near waste incinerators, open air dumps, petrochemical complexes, a cement kiln burning waste, and a medical waste incinerator. The sites were located in the following countries: Czech Republic (3 sites), Kenya, Mexico, Mozambique, Philippines, Slovakia, Turkey, Uruguay, and the USA. Total PBDEs ranged from 0.8 – 106.8 ng/g lipid. PBDE47 ranged from 0.08 – 2.44 ng/g lipid and PBDE99 ranged from 0.13 – 4.56 ng/g lipid. The highest levels of PBDE47 and 99 were observed in Kenya, Mexico, and the USA. (Blake A. International POPs Elimination Network. The next generation of POPs: PBDEs and Lindane. April 2005)

[65] St. Lawrence Estuary beluga whales were analyzed for PBDEs between 1988 and 1999. SigmaPBDE concentrations varied between 20 – 1000 ng/g wet weight with PBDE47, 99 and 100 making up approximately 75% of the total. The whales doubled their blubber concentration of these prevalent PBDE congeners in less than three years. Both sexes accumulated PBDEs. (Lebeuf M, Gouteux B, Measures L, Trottier S. Department of Fisheries and Oceans, Maurice Lamontagne Institute, PO Box 1000, Mont-Joli, Quebec, Canada G5H 3Z4. lebeufm@dfo-mpo.gc.ca Levels and temporal trends (1988-1999) of polybrominated diphenyl ethers in beluga whales (Delphinapterus leucas) from the St. Lawrence Estuary, Canada. Environ Sci Technol 38:2971-2977, June 2004)

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

- general

Workers

[66] PBDEs were measured in the blood of workers in municipal waste incinerator plants and in the general population living nearby in Korea. PBDE47 was a predictive indicator for total PBDE concentration (r – 0.912). The total PBDE concentration among 13 workers ranged from 8.61 - 46.05 ng/g lipid with a mean of 19.33 ng/g lipid and a median of 15.94 ng/g lipid. Levels of PBDEs in the general population ranged from 7.24 – 28.89 ng/g lipid with an average of 15.06 ng/g lipid and median of 14.34 ng/g lipid. The authors point out that the levels of PBDEs observed in Korea are higher than those reported in other countries. (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 336:45-56, January 2005)

[67] PBDEs were measured in the blood of 20 hospital cleaners, 19 workers at an electronics-dismantling plant, and in 20 clerks working full time at computer screens. Workers at the electronics dismantling plant showed the highest levels of all five PBDE congeners. PBDE47 was present in hospital cleaners (median of 1.6 ng/g lipid); computer clerks (median of 1.5 ng/g lipid); and electronics dismantlers (median of 5.9 ng/g lipid). The serum concentrations of all PBDEs declined in electronics dismantlers during summer vacation. Since plasma levels among cleaners and clerks ranged up to one order of magnitude, the authors hypothesize that other exposure sources are probably important for individual exposure. (Sjodin A, Hagmar L, Klasson-Wehler E, Kronholm-Diab K, Jakobsson E, Bergman A. Department of Environmental Chemistry, Stockholm University, Stockholm, Sweden andreas.sjodin@mi.su.se Flame retardant exposure: polybrominated diphenyl ethers in blood from Swedish workers. Environ Health Perspect 107:643-648, August 1999)

P**renatal exposure**

[68] Fifteen human placenta and 13 human fetal liver samples obtained between 1998 and 2003 were examined for PBDEs. Total PBDE concentrations in fetal liver averaged 107 ng/g lipid in 1998 and 1324 ng/g lipid in 2003. PBDE47 concentrations in fetal liver averaged 44 ng/g lipid in 1998 and 218 ng/g lipid in 2003. PBDE99 concentrations in fetal liver averaged 63 ng/g lipid in 1998 and 527 ng/g lipid in 2003. Total PBDE levels in human placenta were 109 ng/g lipid in 2000 (earliest year for which there were samples) and 307 ng/g lipid in 2003. PBDE47 concentrations in placenta averaged 40 ng/g lipid in 2000 and 108 ng/g lipid in 2003. PBDE99 concentrations in placenta averaged 42 ng/g lipid in 2000 and 121 ng/g lipid in 2003. The authors note that the concentrations of PBDEs observed in fetal liver are increasing with time and appear to be greater than levels measured in human milk, maternal blood, and fetal blood on a lipid weight basis. (Doucet J, Douglas A, Cooke G, Goodyer CG. Health Canada, Health Products and Food Branch, Ottawa, Canada; and McGill University Health Centre – Montreal Children's Hospital Research Institue. Brominated Diphenyl Ether (BDE) Residues in Canadian Human Fetal Liver and Placenta. Third

International Workshop on Brominated Flame Retardants, University of Toronto, Ontario, Canada, June 6-9, 2004)

[69] Twelve paired samples of maternal and cord blood from women in Indiana, USA were examined for six congeners of PBDEs. The total PBDE concentration in maternal sera varied from 15 – 580 ng/g lipid. The total concentrations found in cord blood samples varied from 14 – 460 ng/g lipid. Individual fetal blood concentrations did not differ from the maternal concentrations. PBDE47 accounted for 53% - 64% of the total PBDEs in the serum. The study indicates that human fetuses in the USA may be exposed to relatively high levels of PBDEs. (Mazdai A, Dodder NG, Abernathy MP, HItes RA, Bigsby RM. Department of Obstetrics and Gynecology, Indiana University School of Medicine, Indianapolis 46202-5121,USA. Polybrominated diphenyl ethers in maternal and fetal blood samples. Environ Health Perspect 111: 1249-1252, July 2003)

[70] Maternal blood plasma, cord blood plasma, and breast milk were collected from 15 Swedish mothers and analyzed for PBDEs. PBDE47 in maternal blood plasma ranged from 0.3 – 5.1 ng/g lipid with a median of 0.83 ng/g lipid. PBDE47 in cord blood plasma ranged from 0.33 – 3.28 ng/g lipid with a median of 0.98 ng/g lipid. PBDE47 in breast milk ranged from 0.26 – 4.01 ng/g lipid with a median of 1.15 ng/g lipid. PBDE99 in maternal blood plasma ranged from <0.01 – 1.43 ng/g lipid with a median of 0.19 ng/g lipid. PBDE99 in cord blood plasma ranged from <0.01 – 0.85 ng/g lipid with a median of 0.07 ng/g lipid. PBDE99 in breast milk varied from 0.07 – 2.20 ng/g lipid with a median of 0.21 ng/g lipid. PBDE47 constituted 46 – 70% of the PBDEs in breast milk; 31 – 61% of the PBDEs in blood plasma; and 45 – 94% of the PBDEs in cord blood plasma. The authors note that the fetus is probably continuosly exposed to PBDEs, PCBs, OH-PCBs, and PCP during development. (Guvenius DM, Aronsson A, Ekman-Ordeberg G, Bergman A, Noren K. Department of Medical Biochemistry and Biophysics, Karolinska Institutet, Stockholm, Sweden. Daiva.M-Guvenius@mk.su.se Human prenatal and postnatal exposure to polybrominated diphenyl ethers, polychlorinated biphenyls, polychlorobiphenylols, and pentachlorophenol. Environ Health Perspect 111:1235-1241, July 2003)

- as a result of long-range environmental transport

Human Milk

[71] Total PBDE concentrations in human milk from Arctic Quebec in Canada were 6.2 ng/g lipid in 1996 – 2000. The authors note that this is a three-fold increase since 1989 – 1991. (de Wit C, Muir DCG. Institute of Applied Research, Stockholm University, Stockholm, Sweden and National Water Research Institute, Environment Canada, Burlington, Ontario, Canada. Levels and trends of brominated flame retardants in the Artic. Third International Workshop on Brominated Flame Retardants, University of Toronto, Ontario, Canada, June 6-9, 2004 and references therein)

Air

[72] Archived air samples from 1994-1995 collected from the Canadian and Russian Arctic were analyzed for PBDEs. Samples from Alert and Tagish in the Canadian Arctic showed total PBDE (di-HpBDEs) concentrations of 240 pg/m^3 and 424 pg/m^3 respectively. Samples from the Russian Arctic in Dunai showed total PBDE levels of 14 pg/m^3 . The

authors note that levels in Alert and Tagish may be due in part to waste burning. The finding of mon-, di-, and triBDEs in Alert air may indicate debromination during long range transport. Total PBDEs from Norway sampled in 1999-2000 ranged from 3-10 pg/m^3 . The authors note that PBDE47, 99, 100, 153, and 154 were the predominant congeners measure in Arctic air and that PBDE99 had the highest concentrations. (de Wit C, Muir DCG. Institute of Applied Research, Stockholm University, Stockholm, Sweden and National Water Research Institute, Environment Canada, Burlington, Ontario, Canada. Levels and trends of brominated flame retardants in the Artic. Third International Workshop on Brominated Flame Retardants, University of Toronto, Ontario, Canada, June 6-9, 2004 and references therein)

Animal

[73] PBDEs were measured in the livers of frogs collected in Sweden. PBDE47 concentrations were 2.3 and 0.93 ng/g lipid in frogs from Ammarnas and Kiruna and only the Ammarnas samples showed the presence of PBDE99 at 5.6 ng/g lipid. (de Wit C, Muir DCG. Institute of Applied Research, Stockholm University, Stockholm, Sweden and National Water Research Institute, Environment Canada, Burlington, Ontario, Canada. Levels and trends of brominated flame retardants in the Artic. Third International Workshop on Brominated Flame Retardants, University of Toronto, Ontario, Canada, June 6-9, 2004 and references therein)

[74] The global distribution and transport of PBDEs was examined using skipjack tuna (Katsuwonus pelamis) collected from offshore Japan, Taiwan, Philippines, Indonesia, Seychelles, Brazil, and from the Japan Sea, East China Sea, Indian Ocean, and North Pacific Ocean. PBDEs were detected in almost all the fish examined with sigma levels ranging from <0.1 – 53 ng/g lipid. PBDE47, 15, and 28 showed an increasing trend with increasing latitude. The authors conclude that lower brominated congeners were preferentially transported from pollution sources to northern colder regions through the atmosphere. (Ueno D, Kajiwara N, Tanaka H, Subramanian A, Fillmann G, Lam PK, Zheng GJ, Muchitar M, Razak H, Prudente M, Chung KH, Tanabe S. Center for Marine Environmental Studies (CMES), Ehime University, Bunkyo-cho 2-5, Matsuyama 790-8566, Japan. Global pollution monitoring of polybrominated diphenyl ethers using skipjack tuna as a bioindicator. Environ Sci Technol 38:2312-2316, April 2004)

[75] Accumulation and prey to predator transfer of PBDEs was examined in the Arctic in polar cod, ringed seal, polar bear, and beluga whale. PBDE47, 99, and 100 were dominant in all species. In ringed seal PBDE47 accounted for 97% of the PBDEs. The authors use the metabolic index to suggest that PBDE47 and 99 accumulate to same magnitude as PCB 153 in ringed seals and beluga whales. Polar bears are capable of metabolizing PBDEs and are therefore unsuitable as indicators for PBDE contamination in the Arctic environment. (Wolkers H, van Bavel B, Derocher AE, Wiig O, Kovacs KM, Lydersen C, Lindstrom G. Norwegian Polar Institute, N-9296 Tromso, Norway, Hans.Wolkers@npolar.no Congener-specific accumulation and food chain transfer of polybrominated diphenyl ethers in two arctic food chains. Environ Sci Technol 38:1667:1674, March 2004)

[76] "Current PBDE concentrations in marine mammals from the Canadian Arctic are very low at approximately 5 ng/g lipid, but they have increased exponentially with a doubling time of approximately 7 yr. Marine mammals from the rest of the world have current PBDE levels of approximately 1000 ng/g lipid, and these concentrations have also increased exponentially with a doubling time of approximately 5 yr. Some birds' eggs

from Sweden are also highly contaminated (at approximately 2000 ng/g lipid) and show PBDE doubling times of approximately 6 yr. Herring gull eggs from the Great Lakes region now have PBDE concentrations of approximately 7000 ng/g lipid, and these levels have doubled every approximately 3 yr." (Hites RA. School of Public and Environmental Affairs, Indiana University, Bloomington, Indiana 47405, USA. HitesR@Indiana.edu Polybrominated diphenyl ethers in the environment and in people: a meta-analysis of concentrations. Environ Sci Technol 38:945-956, February 2004)

[77] PBDEs were measured in glaucous gulls and polar bears in the Norwegian Arctic. Total PBDE levels (12 congeners) in glaucous gulls ranged from 8.23 – 67.5 ng/g wet weight. Total PBDE levels in polar bears ranged from 2.65 – 9.72 ng/g wet weight. (Verreault J, Gabrielsen GW, Chu S, Muir DC, Andersen M, Hamaed A, Letcher RJ. Norwegian Polar Institute, Tromso, NO-9296, Norway. jonathan@npolar.no Flame retardants and methoxylated and hydroxylated polybrominated diphenyl ethers in two Norwegian Arctic top predators: glaucous gulls and polar bears. Environ Sci Technol 29: 6021-6028, August 15, 2005)

[78] Marine fish and blue mussels from southern Greenland were analyzed for PBDE47, 99, 100 and 153. The highest concentrations were found in uvak, a top predator. Measured sum concentrations varied from 1.2 – 8.2 ug/kg wet weight in fish and 0.11 ug/kg wet weight in blue mussels. (Christensen JH, Glasius M, Pecseli M, Platz J, Pritzl G. Department of Environmental Science, National Environmental Research Institute, Roskilde, Denmark jch@dmu.dk Polybrominated diphenyl ethers (PBDEs) in marine fish and blue mussels from southern Greenland. Chemosphere 47:631-638, May 2002)

[79] In contrast to declining PBDE levels since 1997 in Swedish breast milk, PBDE levels in the Canadian Arctic continue to increase exponentially. Arctic ringed seals (Phoca hispida) were tested for 37 PBDE congeners in 1981, 1991, 1996, and 2000. Total PBDE concentrations increased exponentially over this time period in male seals aged 0 – 15 years. Penta- and hexa-BDEs are doubling approximately every 4 – 5 years while tetra-BDEs are doubling every 8.6 years. The authors note that at current rates of biocaccumulation, PBDEs will surpass PCBs as the most prevalent organohalogen compound in Canadian ringed seals by 2050. (Ikonomou MG, Rayne S, Addison RF. Institute of Ocean Sciences, Department of Fisheries and Oceans Canada, Sidney, British Columbia ikonomoum@pac.dfo-mpo.gc.ca Exponential increases of the brominated flame retardants, polybrominated diphenyl ethers, in the Canadian Arctic from 1981 to 2000. Environ Sci Technol 36:1886:1892, May 2002)

Soil and sediment

[80] Soils from the Chukotka in the Russian Arctic collected in 2000 – 2001 showed detectable concentrations of total PBDEs of 0.16 – 0.23 ng/g dry weight in assays with 0.5 ng/g detection limits in soil. Median levels of total PBDEs in Norway was 0.71 ng/g dry weight in samples with 1.1 ng/g organic matter. The contribution of PBDE47 and 99 to total PBDE concentrations increased going northward. (de Wit C, Muir DCG. Institute of Applied Research, Stockholm University, Stockholm, Sweden and National Water Research Institute, Environment Canada, Burlington, Ontario, Canada. Levels and trends of brominated flame retardants in the Artic. Third International Workshop on Brominated Flame Retardants, University of Toronto, Ontario, Canada, June 6-9, 2004 and references therein)

[81] Sediments from seven lakes in West Greenland had PBDE47 levels of 0.007 – 0.051 ng/g dry weight in the top layer of the core and showed highe concentrations in more recent layers. Total PBDEs in three marine sediments from the Canadian Arctic in Barrow Strait, Penny Strait, and Nanisivik were 0.107, 0.122 and 0.297 ng/g dry weight respectively with PBDE47 as the most prominent congener. Sediments collected from Tromso harbor in Norway showed concentrations of 0.06 – 0.25 ng/g dry weight of total PBDEs and 0.42 – 0.43 ng/g dry weight of PBDE209. Sediments from northwest Russia in Kola Bay and Guba Zapadnaya Litsa contained 0.14 – 0.16 ng/g dry weight of total PBDEs measured as Te-HxBDEs. PBDEs were also measured in Polyarnyy, Russia which contains a navy base and levels were 241 ng/g dry weight with PBDE99 as a the major congener. (de Wit C, Muir DCG. Institute of Applied Research, Stockholm University, Stockholm, Sweden and National Water Research Institute, Environment Canada, Burlington, Ontario, Canada. Levels and trends of brominated flame retardants in the Artic. Third International Workshop on Brominated Flame Retardants, University of Toronto, Ontario, Canada, June 6-9, 2004 and references therein)

Modeling data

[82] Emissions and fate of PBDEs (but not PBDE209) were estimated in a 470 km^2 area of Toronto, Canada using the Multi-media Urban Model combined with measured concentrations. The calculations indicated that 57% - 85% of PBDE emissions to the outdoor environment originate from within Toronto and removal occurs by winds. The authors note that dust ingestion can cause almost 100-fold higher exposure than "average" for a toddler with high dust intake rate in a home with elevated PBDE concentrations. (Jones-Otazo HA, Clarke JP, Diamond ML, Archbold JA, Ferguson G, Harner T, Richardson GM, Ryan JJ, Wilford B. Department of Geography, Centre for Urban Health Initiatives, University of Toronto, 100 St. George Street, Toronto, Ontario, Canada. Is house dust the missing exposure pathway for PBDEs? An analysis of the urban fate and human exposure to PBDEs. Environ Sci Technol 39:5121-5130, July 2005)

[83] Four models were used to examine the long range transport potential of PBDEs: TaPL3-2.10, ELPOS-1.1.1, Chemrange-2, and Globo-POP-1.1. All four yielded comparable predictions that indicated that lower-brominated congeners such as PBDE47 have a similar potential for long range transport as PCBs that known to have significant long range transport. Since three of the models assume a uniform temperature of 25C, the long range transport may be underestimated. (Wania F, Dugani CB. Division of Physical Sciences, University of Toronto at Scarborough, 1265 Military Trail, Toronto, Ontario M1C 1A4, Canada. frank.wania@utoronto.ca Assessing the long-range transport potential of polybrominated diphenyl ethers: a comparison of four multimedia models. Environ Toxicol Chem 22:1252-1261, June 2003)

- information regarding bio-availability

[84] This study assessed the bioavailability of PBDEs in sewage sludge and sediment to the freshwater olgochaete worm, Lumbriculus variegatus. Oligochaetes were exposed to composted sewage sludge containing 1,600 ng/g total PBDEs for 28 days. PBDE47 and 99 were the most prevalent bioavailable congeners present in oligochaetes after exposure. The authors note that accumulation of PBDE congeners from biosolids and sediments by benthos provides a pathway for transfer to higher tropic levels. (Ciparis S, Hale RC. Department of Environmental and Aquatic Animal Health, Virginia Institute of Marine Science, School of Marine Science, The College of William and Mary, Gloucester Point, Virginia 23602, USA

sxcipari@gw.dec.state.ny.us Bioavailability of polybrominated diphenyl ether flame retardants in biosolids and spiked sediment to the aquatic oligochaete, Lumbriculus variegatus. Environ Toxicol Chem 24:916-925, April 2005)

[85] PBDE47, 153, 154 and 183 were found in 32 bleak fish (Alburnus alburnus) from Spain at levels ranking from not detected to 573/ng/g wet weight for total PBDEs. PBDE and HBCD concentrations were correlated with fish length and weight indicating bioaccumulation. The lowest values of PBDEs were found upstream of the industrialized area. The concentrations in this study were compared with a previous study of PBDEs in sediments collected at the same sites. The authors note that the large fish to sediment ratios for PBDEs and HBCD indicate high bioavailability. (Eljarrat E, dela Cal A, Raldua D, Duran C, Barcelo D. Department of Environmental Chemistry, IIQAB, CSIC, JOrdi Girona 18-26, o8034 Barcelona, Spain eeeqam@cid.csic.es Brominated flame retardants in Alburnus alburnus from Cinca River Basin (Spain). Environ Pollut 133:501-508, February 2005)

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

Agency for Toxic Substances and Disease Registry, USA Department of Health and Human Services. Toxicological profile for polybrominated biphenyls and polybrominated diphenyl ethers. September 2004)

Environmental Screening Assessment of Polybrominated Diphenyl Ethers in Canada. As described: Pasternak J, Suffredine L, Taylor. Environment Canada, Third International Workshop on Brominated Flame Retardants, University of Toronto, Ontario, Canada, June 6-9, 2004

(g) Status of the chemical under international conventions

Please see UNEP/POPs/POPRC.1/INF/10 Status of chemicals under consideration in other international forums.