United States Environmental Protection Agency

Technical Fact Sheet – Polybrominated Diphenyl Ethers (PBDEs) and Polybrominated Biphenyls (PBBs)

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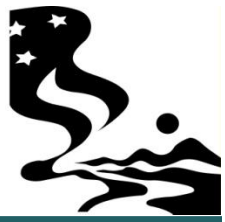

TECHNICAL FACT SHEET – PBDEs and PBBs

At a Glance

- Groups of man-made chemicals that serve as flame retardants for electrical equipment, electronic devices, furniture, textiles, and other household products.
- Structurally similar and exhibit low volatility. Lower brominated congeners of PBDE tend to bioaccumulate more than higher brominated congeners.
- May act as endocrine disruptors in humans and other animals. Exposure in rats and mice caused neuro-developmental toxicity and other symptoms.
- PBBs have been classified as "possibly carcinogenic to humans."
- The American Conference of Government Industrial Hygienists (ACGIH) has established workplace environmental exposure levels (WEEL) for PBDEs and PBBs.
- EPA has developed oral reference doses for decaBDE, octaBDE and pentaBDE.
- Detection methods include gas chromatography, mass spectrometry, and liquid chromatography.
- Treatment methods have not been developed for any environmental medium; potential treatment methods being evaluated at the laboratory scale include debromination using zero-valent iron (ZVI) and enhanced biodegradation using microbial species.

Introduction

This fact sheet, developed by the U.S. Environmental Protection Agency (EPA) Federal Facilities Restoration and Reuse Office (FFRRO), provides a brief summary of the contaminants polybrominated diphenyl ethers (PBDE) and polybrominated biphenyls (PBB), including physical and chemical properties; environmental and health impacts; existing federal and state guidelines; detection and treatment methods; and additional sources of information.

PBB has been banned in the United States since 1973, when PBB accidentally mixed into animal feed exposed 9 million people to contaminated dairy products, eggs, and meat (De Wit 2002; DHHS 2011). In contrast, PBDEs have been in widespread use in the U.S. since the 1970s; however, there is growing concern about their persistence in the environment and their tendency to bioaccumulate in the food chain (EPA OPPT 2010). Since PBDEs and PBBs belong to the same class of brominated hydrocarbons and their chemical structures are similar, they are both discussed in this fact sheet. This fact sheet provides basic information on PBDEs and PBBs to site managers and other field personnel who may encounter these contaminants at cleanup sites.

What are PBDE and PBB?

- PBDE and PBB are classes of brominated hydrocarbons, also referred to as brominated flame retardant (BFR) chemicals. They are structurally similar, containing a central biphenyl structure surrounded by up to 10 bromine atoms (ATSDR 2004).
- They are used in a wide variety of products, including furniture, upholstery, electrical equipment, electronic devices, textiles, and other household products (ATSDR 2004; EPA OPPT 2010; WDLI 2011).
- At high temperatures, PBDEs and PBBs release bromine radicals that reduce both the rate of combustion and dispersion of fire (De Wit 2002).
- Three PBDE homologs are commercially available, including pentaBDE (PeBDE), octaBDE (OBDE), and decaBDE (DeBDE) (De Wit 2002).
- PBDEs exist as mixtures of distinct chemicals called congeners with unique molecular structures. The PBDE congeners may differ in the total number or position of bromine atoms attached to the ether molecule. Congeners with equal numbers of bromine atoms are known as homologs (ATSDR 2004; De Wit 2002).

What are PBDE and PBB? (continued)

- PBBs also exist as mixtures of congeners. They were produced as three primary homologs: hexabromobiphenyl (hexaBB), octabromobiphenyl (octaBB), and decabromobiphenyl (decaBB) (ATSDR 2004; DHHS 2011).
- There are no known natural sources of PBDE and PBB (ATSDR 2004).
- Both PBDE and PBB are structurally similar to polychlorinated biphenyls (PCB). Both PBDE and PBB are fat-soluble and hydrophobic (De Wit 2002; Hooper and McDonald 2000).
- Homologs with the highest numbers of bromine atoms tend to exhibit the lowest volatilities (De Wit 2002; DHHS 2011).
- Even though PBDEs and PBBs are relatively stable, they are susceptible to photolytic debromination when they are exposed to ultraviolet light (De Wit 2002; DHHS 2011).

Exhibit 1: Physical and Chemical Properties of PBDEs and PBBs
(ATSDR 2004; De Wit 2002)

Property	PBDE (Penta-, Octa-, and Deca-BDE)	PBB (Hexa-, Octa-, and Deca-BB)
CAS Numbers	PentaDBE – 32534-81-9 OctaBDE – 32536-52-0 DecaBDE – 1163-19-5	HexaBB – 36355-01-8 OctaBB – 27858-07-7 DecaBB – 13654-09-6
Physical description (physical state at room temperature)	Pale yellow liquid or white powder	White solid
Molecular weight (g/mol)	564 to 959.2 (DecaBDE)	627 to 943
Water solubility (µg/L at 25°C)	1	3 to 30
Boiling point (°C)	>300 to >400	Not applicable
Melting point (°C)	85 to 306	72 to 386
Vapor pressure at 25°C (mm Hg)	2.2×10^{-7} to 9×10^{-10}	5.2×10^{-8}
Octanol-water partition coefficient (log K_{ow})	5.7 to 8.27	5.53 to 9.10
Soil organic carbon-water coefficient (K_{oc})	4.89 to 6.80	3.33 to 3.87 (HexaBB)
Henry's Law Constant (atm m^3/mol)	7.5×10^{-8} to 1.2×10^{-5}	1.38×10^{-6} to 5.7×10^{-3}

Notes: g/mol – gram per mole; µg/L – micrograms per liter; °C – degrees Celsius; mm Hg – millimeters of mercury; atm m^3/mol – atmosphere-cubic meters per mole.

What are the environmental impacts of PBDE and PBB?

- PBDEs may enter the environment through emissions from manufacturing processes, volatilization from various products that contain PBDEs, recycling wastes, and leaching from waste disposal sites (Streets et al. 2006).
- PBDEs and PBBs have been detected in air, sediments, surface water, fish, and other marine animals (Streets et al. 2006).
- Lower brominated congeners of PBDE tend to bioaccumulate more than higher brominated congeners and are more persistent in the environment (De Wit 2002).
- Higher brominated congeners of PBDE tend to bind to sediment or soil particles more than lower brominated congeners (De Wit 2002).
- PBBs bind strongly to soil or sediment particles, which reduces their mobility on the ground but increases their mobility in the atmosphere, where they are attached to airborne particulate matter (ATSDR 2004).
- As of 2004, PBBs had been found at nine National Priorities List (NPL) sites (ATSDR 2004).
- PBDEs were not found at any of the current or deleted National Priorities List (NPL) sites (the total number of sites evaluated was not known). As more NPL sites are evaluated, there is a possibility that PBDE contamination may be discovered at these sites. However, since PBDEs are widely used in commercial products, they may be less prevalent at hazardous waste sites (ATSDR 2004).

What are the health effects of PBDE and PBB?

- The International Agency for Research on Cancer (IARC) classified PBBs as "possibly carcinogenic to humans" (IARC 2011). EPA has not classified PBBs for carcinogenicity.
- Studies on mice and rats have shown that exposure to PBDEs and PBBs cause neuro-developmental toxicity, weight loss, toxicity to the kidney, thyroid, and liver, and dermal disorders (ATSDR 2004; Birnbaum and Staskal 2004; De Wit 2002).
- Studies on animals and human beings have shown that some PBBs and PBDEs can act as endocrine system disruptors and also tend to deposit in human adipose tissue (ATSDR 2004; Birnbaum and Staskal 2004; DHHS 2011; He et al. 2006; McDonald 2002).
- A study has indicated that octaBDE may be a potential teratogen (He et al. 2006).
- According to EPA, decaBDE is described as possessing "suggestive evidence of carcinogenic potential" (EPA IRIS 2008a).
- EPA has established the following oral reference doses (RfD) for PBDEs (EPA IRIS 2008b,c,d; 1990a,b):
  - 7×10^{-3} milligrams per kilogram day (mg/kg-day) for the decaBDE homolog;
  - 3×10^{-3} mg/kg-day for the octaBDE homolog;
  - 1×10^{-4} mg/kg-day for the tetraBDE homolog;
  - 2×10^{-4} mg/kg-day for the hexaBDE homolog;
  - 2×10^{-3} mg/kg-day for the pentaBDE homolog

Are there any existing federal and state guidelines and health standards for PBDE and PBB?

- EPA continues to evaluate and assess the risks posed by PBDEs and PBBs. No federal cleanup standards or guidelines have been set for PBDEs and PBBs (ATSDR 2004; EPA OPPT 2010).
- EPA has issued a Significant New Use Rule (SNUR) to phase out pentaBDE and octaBDE. According to this rule, no new manufacture or import of these two homologs is allowed after January 1, 2005, without a 90-day notification to EPA for evaluation (EPA OPPT 2010).
- The two U.S. producers and the main U.S. importer of decaBDE committed to end production, import and sales of the chemical for all consumer, transportation, and military uses, by the end of 2013 (EPA 2010).
- American Conference of Industrial Hygienists (ACGIH) has developed a (Workplace Environmental Exposure Level) WEEL of 5 milligrams per cubic meter (mg/m^3) for decaBDE, with ongoing air monitoring required if dust levels of penta and octaBDE exceed 5 mg/m^3 (WDLI 2011).
- The Agency for Toxic Substances and Disease Registry (ATSDR) has established a minimal risk level (MRL) of 0.01 mg/kg-day for acute (1 to 14 days) oral exposure to PBBs and an MRL of 10 mg/kg-day for intermediate (14 to 364 days) oral exposure to decaBDE (ATSDR 2010).
- The California Environmental Protection Agency (Cal/EPA) has proposed a No Significant Risk Level of 0.02 micrograms per day (µg/day) for PBBs (Cal/EPA 2006).
- The Occupational Safety and Health Administration (OSHA) has not established occupational exposure limits for PBDEs or PBBs (ATSDR 2004; OSHA 2011).

What detection and site characterization methods are available for PBDE and PBB?

- Analytical methods used for PBDE detection include gas chromatography (GC)-mass spectrometry (MS) for air, sewage, fish, and animal tissues; GC/electron capture detector (ECD) for water and sediment samples; GC/high resolution MS (HRMS) for fish tissue; and liquid chromatography (LC)/GC-MS-flame ionization detector (FID) for sediments (ATSDR 2004).
- Analytical methods for PBB detection include GC-ECD for commercial samples, soil, plant tissue, sediment, fish, dairy, and animal feed; HRMS/GC for fish samples; GC-FID/ECD for soil; and LC-GC-MS/FID for sediment (ATSDR 2004).

What technologies are being used to treat PBDE and PBB?

- Research is being conducted at the laboratory scale on potential treatment methods for media contaminated with PBDEs and PBBs.
- A laboratory study investigated the degradation of a mixture of decaBDE and octaBDE using anaerobic bacteria (He et al. 2006).
- Another laboratory study investigated ZVI as a treatment method for decaBDE. Secondary treatment using cationic surfactants may be required to increase the availability of PBDE molecules for reactions with ZVI (Keum and Li 2005).
- The use of activated carbon has also been investigated in a laboratory study for the treatment of PDBE in sediment (Choi et al. 2003).

Where can I find more information about PBDE and PBB?

- Agency for Toxic Substances and Disease Registry (ATSDR). 2004. Toxicological Profile for Polybrominated Diphenyl Ethers and Polybrominated Biphenyls. www.atsdr.cdc.gov/toxprofiles/tp68.pdf.
- ATSDR. 2010. Minimal Risk Levels for Hazardous Substances. www.atsdr.cdc.gov/mrls/index.html#bookmark02
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- California Environmental Protection Agency (Cal/EPA) Office of Environmental Health and Hazard Assessment. No Significant Risk Levels for Carcinogens and Maximum Allowable Dose Levels for Chemicals Causing Reproductive Toxicity. 2006. http://www.oehha.ca.gov/prop65/pdf/Aug2006StatusReport.pdf
- Choi, J., Onodera, J., Kitamura, K., Hashimoto, S., Ito, H. Suzuki, N., Sakai, S., and Morita, M. 2003. Modified clean-up for PBDD, PBDF and PBDE with an active carbon column—its application to sediments. *Chemosphere*. Volume 53 (6). Pages 637-643.
- De Wit, C. A. 2002. An Overview of Brominated Flame Retardants in the Environment. *Chemosphere*. Volume 46. Pages 583 to 624.
- He, J., K. R. Robrock, and L. Alvarez-Cohen. 2006. Microbial Reductive Debromination of PBDEs. *Environmental Science & Technology.* Volume 40. Pages 4429 to 4434.
- Hooper, K., and T.A. McDonald. 2000. The PBDEs: An Emerging Environmental Challenge and another Reason for Breast-Milk Monitoring Programs. *Environmental Health Perspectives.* Volume 108 (5). Pages 387 to 392.
- Keum, Y-S., and Q. X. Li. 2005. Reductive Debromination of PBDEs by Zero-Valent Iron. *Environmental Science & Technology.* Volume 39. Pages 2280 to 2286.
- McDonald, T. A. 2002. A Perspective on the Potential Health Risks of PBDEs. *Chemosphere.* Volume 46. Pages 745 to 755.
- Occupational Safety and Health Administration (OSHA).Permissible Exposure Limits. 2011. Web site accessed on November 3. http://osha.gov/SLTC/pel/index.html#standards
- Streets, S. S., S. A. Henderson, A. D. Stoner, D. L. Carlson, M. F. Simcik, and D. L. Swackhamer. 2006. Partitioning and Bioaccumulation of PBDEs and PCBs in Lake Michigan. *Environmental Science & Technology.* Volume 40. Pages 7263 to 7269.
- U.S. Department of Health and Human Services (DHHS). 2011. Report on Carcinogens, 12th Edition – Substance Profile on Polybrominated Biphenyls (PBB). http://ntp.niehs.nih.gov/ntp/roc/twelfth/roc12.pdf
- U.S. Environmental Protection Agency (EPA). 2010. DecaBDE Phase-out Initiative. www.epa.gov/oppt/existingchemicals/pubs/actionplans/deccadbe.html
- EPA Integrated Risk Information System (IRIS). 1990a. "Octabromodiphenyl ether (CASRN 32536-52-0)." www.epa.gov/ncea/iris/subst/0180.htm.
- EPA IRIS. 1990b. "Pentabromodiphenyl ether (CASRN 32534-81-9)." www.epa.gov/iris/subst/0184.htm
- EPA IRIS. 2008a. Toxicological review of decabromodiphenyl ether (BDE-299) in support of summary information on the Integrated Risk Information System. EPA 635-R-07-008F. www.epa.gov/ncea/iris/toxreviews/0035tr.pdf

Where can I find more information about PBDE and PBB? (continued)

- EPA IRIS. 2008b. "Decabromodiphenyl ether (BDE-209) (CASRN 1163-19-5)." www.epa.gov/IRIS/subst/0035.htm
- EPA IRIS. 2008c. "2,2',4,4',5,5'-Hexabromodiphenyl ether (BDE-153) (CASRN 68631-49-2)." www.epa.gov/iris/subst/1009.htm
- EPA IRIS. 2008d. "2,2',4,4'-Tetrabromodiphenyl ether (CASRN 5436-43-1)." www.epa.gov/iris/subst/1010.htm
- EPA Office of Pollution Prevention and Toxics (OPPT). 2010. Polybrominated Diphenylethers. Web site accessed on November 7. www.epa.gov/oppt/pbde/
- Washington State Department of Labor and Industries (WDLI). 2011. Workplace Exposure to PBDEs. Web site accessed on November 7. www.lni.wa.gov/Safety/Topics/AtoZ/polybrom/default.asp.
- World Health Organization International Agency for Research on Cancer (IARC). 2011. Agents Reviewed by the IARC Monographs: Volumes 1-96 (Alphabetical Order). http://monographs.iarc.fr/ENG/Classification/index.php

Contact Information

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