Emerging Contaminants – Polybrominated Diphenyl Ethers (PBDE)and Polybrominated Biphenyls (PBB)

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FACT SHEET

At a Glance

- PBDE and PBB are groups of man-made chemicals that serve as flame retardants for electrical equipment, electronic devices, furniture, textiles, and other household products.
- PBBs have been banned in the United States since the early 1970s, but PBDEs continue to be widely used.
- PBDEs and PBBs are structurally similar and exhibit low volatility.
- Some PBDEs and PBBs may act as endocrine disruptors in humans and other animals. Exposure in rats and mice caused neuro-developmental toxicity, and other symptoms.
- DecaBDE homolog has been classified as “possible human carcinogen”.
- PBBs have been classified as “possibly carcinogenic to humans”.
- The American Conference of Governmental and Industrial Hygienists (ACGIH) has established workplace environmental exposure levels (WEEL) for PBDEs and PBBs.
- EPA has developed oral reference doses (RfD) for decaBDE, octaBDE and pentaBDE.
- Treatment methods have not been developed for any environmental media; potential treatment methods being evaluated at the laboratory scale include debromination using zero valent iron (ZVI) and enhanced biodegradation using microbial species.

Introduction

An “emerging contaminant” is a chemical or material that is characterized by a perceived, potential, or real threat to human health or the environment or a lack of published health standards. A contaminant may also be “emerging” because a new source or a new pathway to humans has been discovered or a new detection method or treatment technology has been developed (DoD 2007). This fact sheet, developed by the U.S. Environmental Protection Agency (EPA) Federal Facilities Restoration and Reuse Office (FFRRO), provides a brief summary for 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 (US) since 1973 when it was accidentally mixed into animal feed exposing 9 million people to contaminated dairy products, eggs, and meat (De Wit 2002; DHHS 2005). In contrast, PBDEs have been in widespread use in the US since the 1970s; however, there is growing concern about their persistence in the environment and their tendency to bioaccumulate in the food chain (EPA 2007a). This fact sheet provides basic information on PBDEs and PBBs to site managers and other field personnel who may encounter these contaminants at a cleanup site.

What are PBDE and PBB?

- PBDE and PBB are brominated flame retardant (BFR) chemicals that are used in a wide variety of products, including furniture, upholstery, electrical equipment, electronic devices, textiles, and other household products (EPA 2007a; WDLI 2007; ATSDR 2004).
- At high temperatures, PBDEs and PBBs release bromine radicals that reduce both the rate of combustion and dispersion of fire (De Wit 2002).
- PBDEs exist as mixtures of distinct chemicals called congeners, each with unique molecular structures. The PBDE congeners may differ in the total number and/or position of bromine atoms attached to the ether molecule. Congeners with same number of bromine atoms are known as homologs (De Wit 2002; ATSDR 2004).
- Three PBDE homologs are commercially available, including pentaBDE (PeBDE), octaBDE (OBDE), and decaBDE (DeBDE) (De Wit 2002).

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What are PBDE and PBB? (continued)

- PBBs also exist as mixtures of congeners. They were produced as three primary homologs: hexabromobiphenyl, octabromobiphenyl, and decabromobiphenyl (ATSDR 2004; DHHS 2005).
- 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 2005).
- 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 2005).

What are the environmental impacts of PBDE and PBB?

- PBDEs and PBBs have been detected in air, sediments, surface water, fish, and other marine animals (Streets and others 2006).
- 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 and others 2006).
- As of 2004, PBBs have been found at nine NPL sites, although PBDEs have not been found at any of the current or deleted NPL sites. This may imply that PBDEs are widely used in commercial products and therefore may be less prevalent at hazardous waste sites (ATSDR 2004).
- 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).

Exhibit 1: Physical and Chemical Properties of PBDE and PBB
(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}
Log K_{ow}	5.7 to 8.27	5.53 to 9.1
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; K_{ow} – Octanol-Water Partition Coefficient.

What are the health effects of PBDE and PBB?

- 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 (McDonald 2002; DHHS 2005; Birnbaum and Staskal 2004; He and others 2006; ATSDR 2004).
- A study has indicated that octaBDE may be a potential teratogen (He and others 2006).
- According to EPA's Integrated Risk Assessment System (IRIS), decaBDE has been classified as a "possible human carcinogen." This classification is still under review (EPA 2007b).
- The International Agency for Research on Cancer (IARC) classified PBBs as "possibly carcinogenic to humans" (IARC 2007). EPA has not classified PBBs for carcinogenicity (EPA 2007a).
- 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 (Birnbaum and Staskal 2004; De Wit 2002; ATSDR 2004).

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 standards or guidelines have been set for PBDEs and PBBs (ATSDR 2004; EPA 2007a).
- EPA has established the following oral RfDs for PBDEs: 1×10^{-2} mg/kg-day for decaBDE homolog; 3×10^{-3} mg/kg-day for octaBDE homolog; and, 2×10^{-3} mg/kg-day for pentaBDE homolog (EPA 2007b).
- 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 2007a).
- The ACGIH has developed a WEEL of 5 milligrams per cubic meter (mg/m^3) for decaBDE. Air monitoring may be required if dust levels of penta and octaBDE exceed 5 mg/m^3 (WDLI 2007).
- 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 2007).
- Cal/EPA proposed a No Significant Risk Level of 0.02 micrograms per day (µg/day) for PBBs (Cal EPA 2007).
- The U.S. Occupational Safety and Health Administration (OSHA) has not established occupational exposure limits for PBDEs or PBBs (ATSDR 2004; OSHA 2007).

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

- Analytical methods used for PBDE 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 PBBs include GC-ECD for commercial samples, soil, plant tissue, sediment, fish, dairy, and animal feed; High Resolution-GC-HRMS 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 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 and others 2006).
- Another laboratory study investigated zero valent iron (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).

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.html
- ATSDR. 2007. Minimal Risk Levels for Hazardous Substances. www.atsdr.cdc.gov/mrls/index.html#bookmark02
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- Keum, Y-S., and Q. X. Li. 2005. Reductive Debromination of PBDEs by Zerovalent Iron. *Environmental Science & Technology*, Vol. 39, pp. 2280 to 2286.
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- U.S. Occupational Safety and Health Administration (OSHA). 2007. http://osha.gov/SLTC/pel/standards.html
- U.S. EPA Office of Pollution Prevention and Toxics. 2007a. Polybrominated Diphenylethers. www.epa.gov/oppt/pbde/
- EPA Integrated Risk Information System. 2007b. www.epa.gov/iris
- Washington State Department of Labor and Industries (WDLI). 2007. Workplace Exposure to PBDEs. www.lni.wa.gov/Safety/Topics/AtoZ/polybrom/default.asp
- World Health Organization International Agency for Research on Cancer (IARC). 2007. Agents Reviewed by the IARC Monographs: Volumes 1-96 (Alphabetical Order). http://monographs.iarc.fr/ENG/Classification/Listagentsalphorder.pdf

Contact Information

If you have any questions or comments on this fact sheet, please contact: Mary Cooke, FFRRO, by phone at (703) 603-8712 or by e-mail at cooke.maryt@epa.gov.