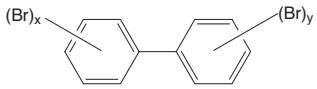
Polybrominated Biphenyls

Separate CAS Nos. are assigned to individual polybrominated biphenyls

Reasonably anticipated to be human carcinogens

First listed in the *Third Annual Report on Carcinogens* (1983)

Also known as PBBs



Polybrominated biphenyls (number of bromine atoms [x + y] = 1–10)

Carcinogenicity

Polybrominated biphenyls (PBBs) are *reasonably anticipated to be human carcinogens* based on sufficient evidence of carcinogenicity from studies in experimental animals. The animal studies used FireMaster FF-1, which is a commercial mixture of polybrominated biphenyl isomers, containing a mixture of pentabromobiphenyls, hexabromobiphenyls, and heptabromobiphenyls.

Cancer Studies in Experimental Animals

Oral exposure to PBBs caused liver tumors in mice and rats. Administration of a commercial mixture of polybrominated biphenyl isomers (FireMaster FF-1) by stomach tube caused liver cancer (hepatocellular carcinoma) in mice and rats of both sexes and bile-duct cancer (cholangiocarcinoma) in rats of both sexes (NTP 1983).

Since PBBs were listed in the *Third Annual Report on Carcinogens,* additional studies in rats and mice have been identified. These studies evaluated the effects of PBBs (FireMaster FF-1) in mice and rats, after (1) dietary exposure of adults, (2) perinatal exposure (dietary exposure of dams prior to breeding and throughout gestation and lactation), and (3) the combined effects of perinatal and adult exposure (NTP 1993). Increased incidences of liver cancer (hepatocellular carcinoma) were observed after dietary exposure of adult mice and rats of both sexes and perinatal exposure of mice of both sexes. In female rats, combined perinatal and adult exposure increased the incidence of liver cancer, compared with adult exposure only. In mice, the high incidence of liver cancer in mice exposed only as adults limited the study's ability to evaluate the combined effects of perinatal and adult exposure on tumor incidence; however, combined exposure increased the number of tumors per animal, compared with adult exposure only, suggesting an enhancing effect.

Cancer Studies in Humans

No epidemiological studies that evaluated the relationship between human cancer and exposure specifically to PBBs were identified at the time they were listed in the *Third Annual Report on Carcinogens.* Since then, a few epidemiological studies have been identified. The International Agency for Research on Cancer reviewed the evidence available in 1986 and concluded that there were no informative studies. Since the IARC evaluation, a case-control study of participants in a PBB-exposure registry in Michigan has been published, which found significant exposure-level-related increases (based on serum PBB concentration) in lymphoma and digestive-system cancer (Hoque *et al.* 1998). Other studies were uninformative.

Properties

PBBs are a class of biphenyl compounds with one to ten hydrogen atoms replaced by bromine. PBBs with three or more bromine atoms are solids with low volatility; volatility decreases with increasing numbers of bromine atoms. PBBs are usually white, off-white, or beige powders at room temperature (IPCS 1994). All of the congeners are insoluble in water but readily soluble in fat. PBBs are extremely stable and therefore persistent in the environment. Hexabromobiphenyl ($C_{12}H_4Br_6$, CAS No. 36355-01-8), one of 101 PBBs compounds in the CAS Registry system, is the main component of the commercial PBB mixtures tested in animal carcinogenicity studies as FireMaster FF-1 (FireMaster was registered as a trademark by the Michigan Chemical Corporation, St. Louis, MI). FireMaster FF-1 was produced by grinding FireMaster BP-6, the other main commercial hexabromobiphenyl PBB mixture (of which the major components were 4.0% pentabromobiphenyls, 62.6% hexabromobiphenyls, and 33.4% heptabromobiphenyls) and blending it with 2% calcium polysilicate as an anticaking agent (NTP 1993). Physical and chemical properties of hexabromobiphenyl, as a representative PBB, are listed in the following table.

Property	Information
Molecular weight	627.6
Melting point	72°C
Log K_{ow}	6.39
Water solubility	0.011 mg/L at 25°C
Vapor pressure	5.2×10^{-8} mm Hg at 25°C

Source: ChemIDplus 2010.

Use

PBBs are no longer used in the United States. Previously, they were used as flame-retardant additives in synthetic fibers and molded plastics. Their major applications were in thermoplastics, mainly acrylonitrile-butadiene-styrene used in electronic-equipment housings. Hexabromobiphenyl was the primary component of the two major products previously used as fire retardants in business-machine housings and in industrial and electrical products. PBBs were also used in smaller amounts as a fire retardant in lacquers and coatings, and in automobile upholstery (ATSDR 2004).

Production

PBBs are no longer produced in commercial quantities in the United States. Three PBB isomers formerly were produced commercially, including hexabromobiphenyl, octabromobiphenyl (CAS No. 61288-13-9), and decabromobiphenyl (CAS No. 13654-09-6). All technical-grade PBBs contained mixtures of several brominated isomers. The sole U.S. producer of hexabromobiphenyl ceased production in November 1974 because of a 1973 incident in Michigan in which the chemical was mistaken for a nutrient additive and 2,000 lb of it was added to animal feed, resulting in the destruction of thousands of farm animals and exposure of many Michigan residents. In 1970, 9,500 kg (21,000 lb) of hexabromobiphenyl and 14,100 kg (31,000 lb) of octabromobiphenyl and decabromobiphenyl were produced. From 1970 to 1974, 11 million pounds of hexabromobiphenyl was produced under the trade names FireMaster BP-6 and FireMaster FF-1. One U.S. firm produced octabromobiphenyl and decabromobiphenyl from 1970 to 1979, and another U.S. firm produced decabromobiphenyl from 1973 to sometime prior to 1977. Estimated U.S. production of PBBs was 170,000 lb in 1975; in 1976, it was 807,000 lb, of all of which was exported (IARC 1986). In 2009, decabromobiphenyl was produced by one company each in China and Europe (SRI 2009) and was available from five suppliers, including three U.S. suppliers (ChemSources 2009). No suppliers were identified worldwide for either hexabromobiphenyl or octabromobiphenyl.

Exposure

The routes of potential human exposure to PBBs are ingestion, inhalation, and dermal contact. Residues remaining in and around facilities that formerly manufactured, processed, or produced products using PBBs are current sources of exposure. In 1973 and 1974, 8,000 to 12,500 Michigan residents were exposed to meat, milk, butter, cheese, and eggs contaminated with PBBs. A general-population survey subsequently conducted in Michigan found that 90% of the population had detectable levels of PBBs in their blood (IARC 1978). In 1976, 524 dairy farmers had a median PBB serum concentration of 2.6 μg/L. In a study conducted in Michigan from 1976 to 1977, 3,639 individuals (mainly farm residents and chemical workers) had a median serum PBB concentration of 3.0 μg/L. Another 1977 study of 3,683 Michigan residents found serum PBB concentrations ranging from less than 1 to 3,150 μg/L, with a geometric mean of 4.1 μg/L. Because PBBs are biologically stable and eliminated slowly, significant body burdens could persist throughout the lifetimes of exposed individuals (IARC 1986).

PBBs have been replaced by polybrominated diphenyl ethers (PBDEs) as brominated fire retardants in textiles, electronic equipment, and plastics (Hanari *et al.* 2006). However, PBBs have been detected as impurities in PBDEs, at concentrations of total PBBs ranging from 58 to 4,025 ng/g in PBDE products. It was estimated that approximately 40 kg of PBBs were emitted annually as a result of the production and use of PBDEs.

In a 1993 study of sport fishers on the Great Lakes (Huron, Michigan, and Erie), those who consumed fish from Lake Huron had the highest mean PBB serum concentration, at 0.6 ng/mL (0.6 μg/L). When the data were stratified by state, sport fishers from Michigan had the highest mean serum concentration, at 0.7 ng/mL (0.7 μg/L) (Anderson *et al.* 1998). In a 1997 study, PBBs were measured in lake trout in the Great Lakes; the mean concentration was highest in fish from Lake Huron, at 3.1 ng/g of wet weight, and lowest in fish from Lake Superior, at 0.13 ng/g (Luross *et al.* 2002). Thirty years after production of PBBs ceased, these compounds were still detectable in the floodplain soils and sediments of Michigan's Pine River, Tittabawassee River, Saginaw River, and Saginaw Bay (Yun *et al.* 2008). A mean concentration of 13.5 ng/g of dry weight in floodplain soil was reported in the lower reaches of the Pine River, near the source of contamination, and a mean concentration of 4.7 ng/g was reported for sediment from the mouth of the Saginaw River, an estimated distance of over 90 km from the source.

In the 2003–04 National Health and Nutrition Examination Survey, BB-153 (hexabromobiphenyl) was evaluated in the serum lipid of 2,032 adults nationwide and was detected in 83%, at a geometric mean concentration of 2.3 ng/g of lipid. Concentrations were highest in U.S.-born individuals over the age of 60 living in houses constructed before 1977 (Sjödin *et al.* 2008). These results corroborated previous findings that showed declining levels of BB-153 in serum from analysis of archived U.S. serum samples collected from 1985 to 2002 (Sjödin *et al.* 2004). The median BB-153 serum concentration was 8.0 ng/g of lipid for 1985 to 1989 and fell in each subsequent reporting period, reaching 3.3 ng/g for 2000 to 2002. BB-153 serum concentration was inversely correlated with collection year ($R = -0.51$, $P < 0.01$).

Workers at companies that manufactured PBBs may have been exposed by skin contact, inhalation, or unintentional ingestion. At one U.S. manufacturer, hexabromobiphenyl was detected at concentrations of 1.1 to 1,729 ppb in the workers' serum and 0.51 to 581 ppm in their adipose tissue (IPCS 1994). At an electronics recycling facility in Sweden, PBBs were measured in air at concentrations of up to 57 ng/m^3 near a shredder that ground plastic housings of electronic equipment containing brominated fire retardants and 0.024 ng/m^3 in the area where new circuit boards were assembled from recycled materials (Sjödin *et al.* 2001).

Regulations

Environmental Protection Agency (EPA)

Emergency Planning and Community Right-To-Know Act

Toxics Release Inventory: Listed category of substances subject to reporting requirements.

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