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Chain of Contamination: The Food Link (Fact Sheet)

POLYBROMINATED DIPHENYL ETHERS (PBDEs)

Background

PBDEs are class of "brominated" (bromine containing) man-made chemicals used as flame retardant additives in plastics, foams and textiles since the 1970's. They are found in numerous consumer applications such as furniture, electronic appliances (e.g. TVs and computers), electrical wiring, car interiors, soft furnishings and carpets. There are a total of 209 individual forms (congeners) of PBDE, which differ in their number of bromine atoms and their pattern of bromination (where the bromine atoms are attached). There are three commercially produced PBDEs, all of which are actually mixtures (formulations) named after the constituent which predominates in the mixture. These are penta-BDE (where the predominant constituent has five bromine atoms), octa-BDE (eight bromine atoms) and deca-BDE (ten bromine atoms). Penta- and octa-BDE are now banned in the EU, but deca-BDE is still widely used. Demand for flame retardants has increased due to fire safety standards in consumer products and PBDEs are produced and used worldwide on a large scale (Peters, 2006) Deca is particularly used on upholstery textiles and curtains in Britain and the Republic of Ireland, which both have strict fire safety regulations. The global demand for PBDEs was estimated to be almost 70,000 tonnes in 2001, with deca-BDE accounting for almost 80% of the total market (Bromine Science and Environmental Forum, from Peters, 2006).

PBDEs are ubiquitous environmental contaminants and have been measured in air, soil, sediment, and water (Hale et al., 2006, Hassanin et al., 2004, Hites, 2004), often far from sources of release, raising concern over their possible global impacts. Their concentrations have increased markedly and now approach those of PCBs in some parts of the world (Hale et al., 2006). PBDEs are very persistent in the environment and some bioaccumulate to a great extent (build up in the tissues of living organisms). They have been detected in wildlife including fish, birds (particularly marine species and in their eggs), and marine mammals such as seals, dolphins and killer whales (Hites, 2004, Kalantzi et al., 2005, Ramu et al., 2005, Rayne et al., 2004). PBDE levels have been shown to be increasing exponentially in wildlife in areas such as the Arctic (Ikonomou et al., 2002). They have been detected in blood, adipose tissue and breast milk samples from humans all over the world (Kalantzi et al., 2004, Hites, 2004) and also in umbilical cord blood (Mazdai et al., 2003).

There are considerable environmental and toxicological concerns regarding PBDEs due to their persistent and bioaccumulative properties, their structural similarity to PCBs (polychlorinated biphenyls) and their potential endocrine disrupting and neurodevelopmental effects. In fact, penta- and octa-BDE flame retardant formulations are now banned in the EU (the legislation came into force in 2004 http://www.opsi.gov.uk/si/si2004/20040371.htm). Their phase out was prompted by evidence of increasing levels in the environment and biota, including humans and in particular, a Swedish study which revealed exponential increases of these PBDEs in breast milk (Mieronyté et al., 1999).

Concerns about deca-BDE are not only related to research which suggests it can act as a developmental neurotoxicant, but are also focussed on its potential to break down into lower brominated forms, which are more bioaccumulative. In addition, it has also been highlighted that when burnt PBDEs can form brominated dioxins and furans, which are also a concern in their own right.

Major uses

PBDEs are used extensively as flame retardants in plastics, textiles and foams. Before being banned, penta-BDE was widely used in polyurethane foam for furniture, upholstery and building materials, and octa-BDE was used in housings for televisions, computers and other electronics. The only remaining PBDE, deca-BDE (or "deca", where the predominant congener is BDE209), is used in as a flame retardants in plastics used in cars and consumer goods such as electrical appliances (TVs, mobile phones, computers), wiring and cabling, and building materials (BSEF, 2005). DecaBDE is also used in textiles and furnishings (sofas, office chairs) (BSEF, 2005, Peters, 2006). PBDE mixtures are non-bound additives in plastics and textiles (i.e. simply mixed with the materials) and can therefore escape from the product over its lifetime (Hooper and McDonald, 2000). Brominated flame retardants such as PBDEs slow down or inhibit the initial phase of a developing fire due to the fact that halogen (bromine) atoms are released during thermal decomposition, removing high energy radicals formed during fire (Peters, 2006).

How do PBDEs get into the environment (and food chain)?

PBDEs may be released into the environment in the following ways: during manufacture of the chemical itself; incorporation into materials (e.g. plastics, textiles); processing of materials into finished articles; during the lifetime of the article (for example "leaching" from foam, furniture and electrical appliances); following leaching from landfill sites (from discarded articles containing PBDEs); or during incineration. Through these routes, PBDEs can end up in indoor and outdoor air, water, soil, sediment and the food chain, where they can accumulate in wildlife, such as fish and higher predators.

How are people exposed to PBDEs?

While it is established that the main exposure route for many persistent pollutants (such as PCBs and DDT) is through the diet (consumption of contaminated food), it appears that inhalation of indoor air and dust is a more significant source of exposure with respect to PBDEs (Stapleton et al., 2005, Wilford et al., 2005, Jones-Otazo et al., 2005, Schecter et al., 2005). PBDEs can get into indoor air and dust after escaping from consumer products in the home such as furniture, carpets and electrical and electronic appliances.

PBDEs in food

In addition to the inhalation route, diet is an important source of exposure to PBDEs, particularly fatty foods such as oily fish, meat and dairy products. For examples of studies of PBDEs in food, see table 1 below.

Food item(s)	Reference(s)	Comments
Fish, shellfish, fish oils	Food Standards Agency UK (Feb 2006) – Brominated chemicals in farmed and wild fish and shellfish and fish oil dietary supplements. Food Survey Information Sheet 04/06 www.food.gov.uk/science/surveillance	Analysis of 48 farmed and wild species of fish and shellfish and 10 fish oil samples. PBDEs found in most samples.
Fish (trout and eel)	Food Standards Agency UK (April 2004) - Brominated flame retardants in trout and eels from the Skerne-Tees river system and total diet study samples. Food Survey Information Sheet 52/04	Analysis of PBDEs (and another brominated flame retardant, HBCD) in trout and eel caught at various locations in Skerne-Tees river system, UK. PBDE & HBCD congeners detected in

		majority of samples, with elevated concentrations found in fish caught downstream of a flame retardant manufacturing site.
Salmon (farmed and wild)	Hites et al (2004). Env. Sci. Technol., 38(19), pp4945-4949	Higher levels of PBDEs found in farmed salmon
Tuna	Ueno et al (2004). Env. Sci. Technol., 38(8), pp2312-2316	Worldwide survey of PBDEs in skipjack tuna.
Meat/fowl (chicken, duck, goose, turkey, pheasant, beef, deer)	Luksemberg et al., (2004). Organohalogen compounds, 66, pp3982-3987	PBDEs, PCDD/Fs and PCBs in fish, beef and fowl purchased in N. California food markets
Meat (hamburger, bacon, chicken fat, pork fat, beef fat)	Huwe J.K. & Larsen, G.L. (2005). Env. Sci. Technol., 39 (15), pp5606-5611.	Analysis of PBDEs, PCBs, dioxins and furans in US meat
Various (including bacon, catfish, wieners, pork sausage, ground beef, ice cream, yoghurt, butter, cheese, soy formula & eggs)	Schecter et al., (2004). Env. Sci. Technol., 38 (20), pp5306-5311	Market basket food survey of 30 food types from US supermarkets.
Various (As part of Total Diet Survey: including bread, meat, dairy products vegetables, oils and fats, poultry, preserves, nuts).	D'Silva, K. (2006). Dietary exposure to PBBs, PBDEs, and PBDD/Fs in the UK (Central Science Laboratory, York, U.K). Presented at "1st Network Conference On Persistent Organic Pollutants-Human Exposure and Impacts" Birmingham, March 2006.	All food groups investigated contained PBDEs "Exposure not just from fish and meat" "Vegetables and fruit also contribute to total exposure"
Various (UK Total Diet samples incl vegetables, bread, meat, eggs, milk, nuts, poultry, sugar)	Food Standards Agency UK (June 2006) – Brominated chemicals: UK dietary intakes. Food Survey Information Sheet 10/06.	BDE-209 (decaBDE) and BDE-47 most abundant PBDEs detected. Detected in most foods.

Table 1: PBDE residues in food items – examples from the literature

Unchanged PBDEs may stay in your body for many years. PBDEs are stored in adipose tissue (body fat) and can be found in the lipid (fat) portion of the blood (Johnson-Restrepo et al., 2005, Thomas et al., 2006). PBDEs can also concentrate in breast milk fat, such that newborn babies can be exposed through breast feeding (Hooper and McDonald, 2000, Kalantzi et al., 2004)). The developing foetus can also be exposed *in utero* to PBDEs via the placenta and mothers blood supply (Mazdai et al., 2003). Whilst research has shown widespread bioaccumulation of penta- and octaBDE in humans and wildlife (e.g. Hites, 2004), it was assumed that decaBDE was too large a molecule to be able to enter cells and bioaccumulate. This has since been discounted as decaBDE has been found in humans – both children and adults (e.g. Fangstrom et al., 2005, Thuresson et al., 2005) and was even found in WWF's biomonitoring studies (www.wwf.org.uk/chemicals/publications). In families, PBDEs have also been found in higher levels in the children (Fischer et al., 2006). Occupational exposure occurs in people working with PBDEs or flame retarded materials (Jakobsson et al., 2002, Sjodin et al., 1999, Thuresson et al., 2005).

What health effects are associated with exposure to PBDEs?

There is limited information on the health effects of PBDEs in people, but animal studies have shown PBDEs to be capable of endocrine disruption and effects on behaviour, development of the brain and nervous system (suggesting effects on the thyroid system), sexual development and behaviour, and reproductive endpoints have all been reported. The nervous system and thyroid are still developing in the foetus and infants meaning the effects of PBDEs on these systems might be more significant if exposure occurs during the periods before and soon after birth. This combined with their structural similarities to the persistent, carcinogenic PCBs (which have a long list of effects on humans and wildlife – see PCB factsheet) has raised concerns about the impacts of long term, low level exposure to PBDEs.

Subtle behavioural changes have been observed in animals exposed to PBDEs during early stages of their development. *In utero* exposure to a low dose of BDE-99 (a constituent of pentaBDE) disrupts neurobehavioral development and causes permanent effects on the rat male reproductive system, which become apparent in adulthood (Kuriyama et al., 2005). One possible explanation for the behavioural disruption might be related to effects in the thyroid, because development of the nervous system is dependent on thyroid hormones. PBDEs have been shown to interfere with sexual development and sexually dimorphic behaviour (Lilienthal et al., 2006). Prenatal (during pregnancy) exposure to BDE-99 resulted in decreases in circulating sex steroids in male offspring at weaning and in adulthood. Puberty onset was delayed in female offspring and the number of ovarian follicles was reduced in females. Behaviour differences between male and female offspring were also disrupted. There are also concerns over the neurodevelopmental effects of PBDEs. Neonatal exposure to decaBDE (BDE-209) and other PBDE congeners has been shown to induce developmental neurotoxic effects (impaired learning and memory, disrupted behaviour) in adult mice, effects that can worsen with age (Viberg et al., 2003a, b, 2006).

It is unclear if PBDEs can cause cancer in people. Based on the evidence of cancer in animals, decaBDE is classified as a possible human carcinogen by the US-EPA (Environmental Protection Agency). The International Agency for Research on Cancer (IARC) has not classified the carcinogenicity of PBDEs.

How can exposure to PBDEs be reduced?

Octa- and penta-BDE are now banned in the EU so alternatives will be readily available. Many manufacturers are moving away from the use of decaBDE in their products (electrical and electronic appliances, furniture, textiles) so it is worth asking when buying such products if you want to avoid these chemicals. Some of the companies which have phased out PBDEs and other brominated flame retardants from their products can be found on the WWF UK safer shopping website - http://safershopping.wwf.org.uk

Regular vacuuming and airing of homes can help reduce dust build up and concentrations of PBDEs in indoor air. This is suspected of being a major exposure route to these chemicals. Eating less meat, dairy and fatty foods might also help to reduce exposure, as PBDEs preferentially accumulate in these kinds of foods. With respect to the consumption of oily fish, where PBDEs and other organic contaminants have been shown to accumulate, it is worth following the FSA's guidelines which can be found on their website.
http://www.food.gov.uk/science/surveillance/fsisbranch2006/fsis0406.

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Further information

http://www.atsdr.cdc.gov/tfacts68-pbde.html
http://www.atsdr.cdc.gov/toxprofiles/phs68-pbde.html
www.checnet.org/healthehouse/home/index.asp