Appendix 2 to the ACAP report

Brominated Flame Retardants

What are Brominated Flame Retardants?

Polybrominated diphenylethers (PBDEs) are one of the four main classes/substances that are commonly referred to as **Brominated flame retardants** (BFRs); the others being polybrominated biphenyls (PBBs), tetrabromobisphenol A (TBBPA) and Hexabromocyclododecan (HCDB).

Brominated flame retardants are used extensively in a variety of consumer products such as in thermoplastics and circuit boards for electrical equipment (including TVs and computers), building materials, foams for furniture and insulation materials, as well as in textiles and upholstery.

The use of Brominated flame retardants has increased drastically over the past two decades, and worldwide production is now ca. 200 000 tonnes per year. Polybrominated diphenylethers represent about a third of the total production of BFRs.

As a result of their similarity in chemical properties (extremely stable, accumulate in the food chains and in sediments and degrade very slowly), high volume production, and widespread use, comparisons are often drawn between PBDEs and PCBs.

Production and Use

The most important PBDEs are the **penta-BDEs**, **octa-BDEs** and **deca-BDEs**.

They are used in electrical and electronic equipment (including computers, TVs), textiles and plastics in vehicles, building materials, paints and insulation foam, in order to reduce fire risk. Previously most concern has been expressed over polybrominated biphenyls (PBB), which have similar properties to PCBs, and whose use is fairly restricted. Last years also polybrominated diphenyl ethers (PBDEs), hexabromcyclododecan (HBCD) and tetrabromobisphenol a (TBBP-A) have been examined for serious health and environmental hazards.

The dominating producers of Brominated flame retardants are situated in USA, Israel and the Netherlands, but the substances are included in a wide range of products which are used in the industrial areas of the northern hemisphere that are potential source regions to the Arctic.

Chemical Properties

BFRs are either chemically incorporated in materials during their production or applied as an additive to the material. Those applied as additives, including PBDEs, can more easily migrate into the environment.

In addition to 'gradual leakage' from products, PBDEs are dispersed to the environment in sewage sludges, during disassembly and disposal of electrical equipment, and other waste disposal, including incineration.

Penta- and octa-BDEs are persistent and lipophilic compounds; these physical properties encourage long-range transport and bioaccumulation, in particular of penta-BDEs. Deca-BDEs are characterized as semi-persistent, they are lipophilic but bioaccumulate to a lesser extent. Biological metabolites of PBDEs include methoxymetabolites and deca-BDEs is thought to be capable of breaking-down to form lower-BDEs and polybrominated dibenzofurans.

There are environmental concerns about the possible formation of dioxins and furans when PBDEs are incinerated, for example polybrominated dibenzofurans from deca-BDEs.

Human Effects

Some of the Brominated flame retardants have shown acute toxicity towards water organisms. Many of the substances are persistent and accumulate in the food-chain.

PBDEs have also been found to contaminate human breast milk in Sweden (Darnerud et al., 1998). Swedish research has found that PBDEs were present in the blood of office workers who use computers, and also in hospital cleaners and workers at an electronics-dismantling plant. The highest levels were in the latter, demonstrating the role of electrical goods in the contamination (Sjordin et al., 1999). It has also been reported that TBBP-A has been found in the blood of office workers (ENDS, 1998). In areas outside the Arctic, PBDEs have been found up in human breast milk as well as in the tissues of several animal species.

Heating (for example during manufacture of plastics) and burning of materials containing PBBs, PBDEs and other Brominated flame retardants can produce polybrominated dibenzo-*p*-dioxins and dibenzofurans, which have similar toxicological effects to chlorinated dioxins(WHO, 1998).

It has been reported that TBBP-A is active in a breast cancer cell assay; its chemical structure is very similar to bisphenol a.

Research has shown that low level exposure of young mice to PBDEs causes permanent disturbances in behaviour, memory and learning (Eriksson et al., 1998). PBDEs have also been shown to disrupt the thyroid hormone system in rats and mice; these systems are a crucial part of the development of the brain and body (Darnerud and Thuvander, 1998; Hallgren and Darnerud, 1998). Octa-BDE will be classified and labelled as both liable to impair fertility and developmentally toxic in the course of 2003 in EU.

Typical values of PBDEs (mainly BDE 47 and BDE 99) in plasma are in the range 5 to 40 ng/L (about 0.5% of levels of PCBs) (Darnerud *et al.*, 2001). Blood levels in Canada, however, are up to 10 times higher than those found in Europe, and in the USA up to 10-100 times higher (with levels over 500 ng/g lw reported). Levels of PBDEs in breast milk are also reported to be 5-10 times higher in the USA (upto 200 ng/g lw) than in Europe.

Studies of Arctic populations are currently being carried out.

Increasing Environmental Levels

In the Arctic, PBDEs have been detected in air and in biological samples from remote areas, although their levels are much lower than levels of some legacy POPs, such as PCBs (AMAP, 2002). Recent results from southern Greenland also point to local PBDE contamination, possibly from consumer products used in the settlements. That BFRs are found in air and biological samples from remote areas of the Arctic supports the indications that these substances are globally distributed in the environment. Although deca-BDE (BDE 209) accounts for most PBDE use, the most commonly found congeners are the tetra- and penta- derivatives. In general data on deca-BDEs are lacking as laboratories have only recently developed the capability to analyses these components.

Studies of beluga blubber from southeastern Baffin Island, Canada, show that the levels of PBDEs have increased from 1982 to 1996. The levels are low compared to PCBs in the same animals, but the levels doubled in only three years. The trend parallels PBDE increases in fish and in herring gull eggs from the Great Lakes in North America. A similar increase has also been seen in ringed seal from Holman Island, Canada, with a doubling of concentration in 4.5 years, and in seabirds from Prince Leopold Island, Canada.

Alarmingly high levels (1 and 0,4 mg/kg) of Brominated flame retardants have recently been found in burbot-liver and trout in Mjøsa, the largest lake in Norway. (Martin Schlabach og Eirik Fjeld, personal communication, 2003).

If nothing is done to reduce emissions and current trends continue, PBDEs may reach the same levels as PCBs in a few decades.

Analytical Issues

With increasing availability of reference compounds, quantification of the major congeners can be achieved. However, a complete identification and quantification of all BFRs is not yet possible, and deca-BDEs (e.g. BDE 209) are often omitted when PBDEs are reported.

International efforts and some countries legislation and measurements

OECD
In 1995 a Voluntary Industry Commitment for risk reduction of Brominated Flame Retardants (BFR) was agreed within the **OECD** concerning tetrabromobisphenol-A (TBBPA), polybromobiphenyls (PBB) and polybromodiphenylethers (PBDE).

At the 34th Joint Meeting of the Chemicals Committee and the Working Party on Chemicals, Pesticides and Biotechnology in November 2002, it was decided to organise a Clearinghouse Meeting and to discuss data gaps with industry and to identify possible next steps. A report would be prepared, following the meeting, and presented to the February 2004 Joint Meeting.

EU
EU has adopted restrictions on the marketing and use of penta-BDE and octa-BDE from the 15th August 2004. The EU risk assessment program on deca-BDE was concluded in August 2002. A risk reduction strategy should be finalised before 30th of June 2003. In addition the risk assessments and further testing of

hexabromocyclododecan (HBCD) and TBBPA are being carried out as part of the same programme.

According to the Directive on the restriction of the use of certain hazardous substances in electrical and electronic equipment (RoHS Directive) the manufacturers are required after the 1st of July 2006 to substitute certain heavy metals and the Brominated flame retardants PBB and poly-BDE in new electrical and electronic equipment in order to prevent problems during the waste management phase.

The Waste Electrical and Electronic Equipment (WEEE Directive) was adopted the 27th of January 2003 and will be implemented gradually until 2007. One of the elements in the directive is to require that flame-retarded plastic has to be separated out from other waste from electrical and electronic equipment and this plastic has to be recycled, incinerated or deposited at approved facilities.

Denmark
The Danish Environmental Protection Agency adopted an action plan in 2001. The objective of the Action Plan is the international phase-out of the use of the most problematic Brominated flame retardants, especially the PBBs and PBDEs. The use of all flame retardants that can be released from products should be avoided if they are persistent, can accumulate and if they are suspected of having harmful effects on the environment and/or health.

Sweden
In 1999 the Swedish authorities decided that the use of PBB, PBDE, TBBPA and HBCD should end as soon as possible. After this decision they have been working within different forums to achieve this goal.

Norway
The Norwegian Government adopted in 2002 a new action plan to substantially reduce emissions of Brominated flame retardants by 2010. The plan includes risk reduction measures such as a prohibition against the use of specific substances, information activities, the collection of data and stricter control of waste collection and treatment.

Other international bodies
Other international efforts are also under way to limit the use of Brominated flame retardants. They are included on **OSPAR**'s list of chemicals for priority action to protect the marine environment. At the 4th **North Sea Conference**, it was decided to phase out the use of Brominated flame retardants by 2020. The Nordic countries are seeking to have penta-BDE included in the **global Convention on Persistent Organic Pollutants (POPs).**

PBDEs are not yet a part of US EPA's lists of persistent, bioaccumulative and toxic compounds. In California, however, there is a proposal to introduce state legislation which, if passed, would apply bans similar to those in Europe.

Alternatives to BFRs

Alternatives for PBDEs exist, however their potential for environmental and human health effects are generally not well studied.

In Europe, phase-out of PBDEs has lead to their replacement with other types of Brominated flame retardants, such as tetrabromobisphenol-A (TBBPA) and hexabromocyclododecane (HBCD). PBBs for use as an additive flame retardant are no longer produced.

Other alternatives are inorganic chemicals, which may not be as effective in fire retardation and may themselves be toxic. These include antimony oxides, magnesium or aluminum hydroxide, phosphorus and boron-based compounds, zinc sulphide and zinc oxide, and expandable graphite (see http://www.svtc.org/hu_health/edcs/bfrs/pbdes/danishepa.htm#kap8).

What can the Arctic Council do?

The monitoring and assessment of these substances should be continued and widened. Arctic Countries should give increased attention to these substances through the AMAP coordinating work.

Any ACAP actions have to be further developed before a project proposal can be presented to the Arctic Council for consideration.

However, as far as we are updated on these problems, substituting the most problematic Brominated flame retardants with other non persistent and non bio accumulative substances should be the major task to look into. Hence cooperation with the main producer could be one idea to follow up.

Another important task is to find the best technologies and conditions to destruct or incinerate these substances. Environmentally sound waste handling may reduce the emissions from products already on the market.
Thus exchange of information and eventually give guidance to the Arctic Countries could be another important line to follow.

Other activities that the Arctic Council could look into are:

- Encourage national legislation to ban/restrict use of PBDEs in Arctic countries
- Support proposed phase-out of PBDEs in other countries
- Promote future consideration of PBDEs for inclusion under Stockholm Convention and UN ECE POPs Protocol
- Support the development and introduction of alternatives to PBDEs (including the establishment of risk assessments on chemical alternatives, and consideration of alternative practices that might reduce the need for flame retardants)

The ACAP Interim Steering Committee will initiate work to follow up these ideas and eventually propose a project to the next Ministerial, of course in close contact with other organizations in order not to overlap their activities.
So far the cost of the preparation of such a project is estimated to be of in kind character (travel and participation cost).

References

AMAP, 2002. Arctic Pollution 2002. Arctic Monitoring and Assessment Programme (AMAP), Oslo, Norway. xii+112p.
Darnerud, P.O., G.S. Eriksen, T. Johannesson, P.B. Larsen and M. Viluksela, 2001. Polybrominated diphenyl ethers: Occurrence, dietary exposure and toxicology. Environmental Health Perspec- tives, 109:49–68.
Hooper, K. & McDonald, T. The PBDEs: An Emerging Environmental Challenge and Another Reason for Breast-Milk Monitoring Programs, Environmental Health Perspectives, Vol 108; No 5, May 2000
McDonald, T., A Perspective on the Potential Health Risks of PBDEs, Chemosphere 46:745-755, 2002.

Selected PBDE links:

Canada:
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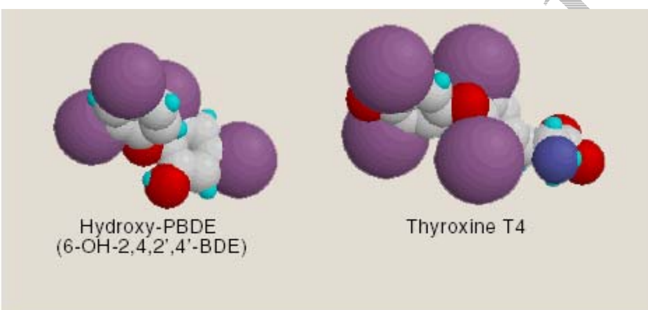
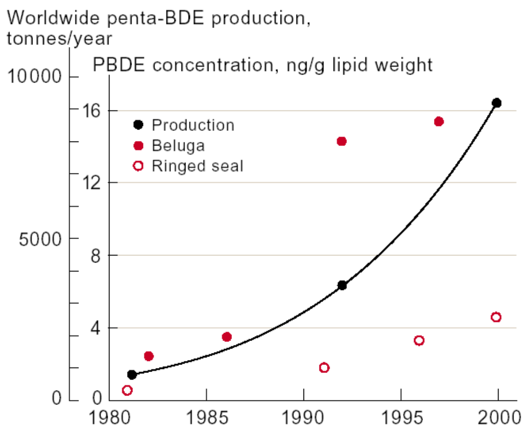
Danish: http://www.svtc.org/hu_health/edcs/bfrs/pbdes/danishepa.htm#kap8

Swedish
xxx

United States:
www.usepa.gov/pbt (US EPA Office of Pollution Prevention and Toxics, Persistent, Bioaccumulative and Toxic (PBT) Chemical Program)



Structural similarities between hydroxy-PBDE and the natural hormone thyroxine T4.



Comparison of temporal trends of PBDEs in ringed seal and beluga in the Canadian Arctic with estimated global production of penta-BDE over the same period.