Comparison of Total Consumer Exposure to PBDEs in Europe and North America

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Introduction

Flame retardants (FRs) are substances added to polymeric materials to inhibit the ignition and/or spread of flames. FRs can be chemically inserted into the polymer molecule (reactive FRs) or be physically blended in polymers after polymerization (additive FRs). Plastics can contain up to 30% of organic FRs or even up to 80% of inorganic FRs (Morf and BUWAL 2002). Materials treated with FRs are mainly used in electronic devices and equipment, textiles, insulating foam and other construction materials and for plastics used in means of transportation (de Wit 2002; Morf and BUWAL 2002).

FRs are classified into inorganic, halogenated, organophosphorus and nitrogen based FRs (IPCS 1997). PBDEs are brominated FRs (BFRs), a subgroup of the halogenated FRs. BFRs had a worldwide market volume of approx. 200'000 tonnes in 2001. PBDEs had a market share of 33% among the BFRs with DecaBDE being the most important product (83%) (BSEF 2003).

Due to their persistent and hydrophobic nature, PBDEs are ubiquitous contaminants in the environment with a tendency to bioaccumulate in food webs (Burreau et al. 2004). PBDEs can be found in birds, mammals, humans, fish and shellfish (de Wit 2002; Tittlemier et al. 2004). They have also been measured in air, soil, dust, sewage sludge and sediments (de Wit 2002; Wilford et al. 2005).

Early assessments of consumer exposure to PBDEs focused on the exposure via food and found that fish and shellfish contribute most to exposure to PBDEs (Bocio et al. 2003). A strong relationship between the amount of fish consumed and the measured levels of PBDEs in human milk of nursing women in Japan has been found (Ohta et al. 2002). Wilford found high concentrations of PBDEs in house dust that may explain the measured variances of PBDE concentrations in human milk and blood (Wilford et al. 2005). The most recent and comprehensive assessment of exposure to PBDEs (Jones-Otazo et al. 2005) focused on four typical scenarios (normal consumer, fish-eater, high indoor dust concentration and computer recycling worker) and differentiated five consumer groups (infants, toddlers, children, teenagers and adults). It is suggested that the inadvertent ingestion of dust and soil may be the most important contributor to PBDE intake even for adults.

In the present work we estimated the total internal exposure to PBDEs in North American and European consumers to understand why the measured concentrations in breast milk of women in the US are 10 to 100 times higher than those in mother's milk from Sweden (Schecter et al. 2003). To this end we use a scenario-based assessment method.

Materials and Method

The method that has been applied to assess the exposure of consumers to chemicals is called Scenario-Based Risk Assessment (SceBRA) (Scheringer et al. 2001). This method has already been used to assess the exposure of various consumer groups (infants, toddlers, children, teenagers and adults) to musk fragrances and phthalates (Wormuth et al. 2005; Wormuth et al. 2006). The investigation with SceBRA considers exposure occurring via food, dust, indoor air (including e.g. automobiles) and direct contact with consumer products. Every exposure pathway is represented by a set of scenarios

that represent the variable PBDE concentrations in contact media (food, water, air, etc.) and the different life styles of consumers in Europe and North America (e.g. food consumption or activity patterns). Minimal, medium and maximal exposures are calculated for each scenario and the likelihood of different magnitudes of exposure is estimated.

As the aim of a SceBRA study is to calculate the total internal exposure to a specific chemical, i.e. to find all relevant exposure scenarios, the results have to be evaluated by comparison with measurements of PBDEs found in the human body.

Results and Discussion

Our preliminary results (Trudel et al. 2006) are shown in figure 1. It can be seen that infants have the highest exposure to PBDEs followed by toddlers and children. The range of exposure for infants in North America (NA) is between 8 and 800 ng/kg/d (medium: 51 ng/kg/d) and in Europe (EU) between 1 and 130 ng/kg/d (medium: 8 ng/kg/d). Teenagers and adults have the lowest exposures with a range of 0.1 to 70 ng/kg/d (medium: 0.8 ng/kg/d). Generally the values of the minimum and maximum scenarios vary by two orders of magnitude.

A significant difference in the modelled exposure to PBDEs between North American and European consumers can only be shown for infants. Except for the maximum exposures that are slightly increased in North America compared to Europe, the total internal exposure levels for toddlers, children, teenagers and adults are all in the same range regardless of the region.

A closer look at the relative importance of three contact media in table 1 reveals that food is generally the most important media for the minimum and medium scenarios whereas dust is most important for maximum scenarios. Air and soil (not shown in table 1) are considerably less important.

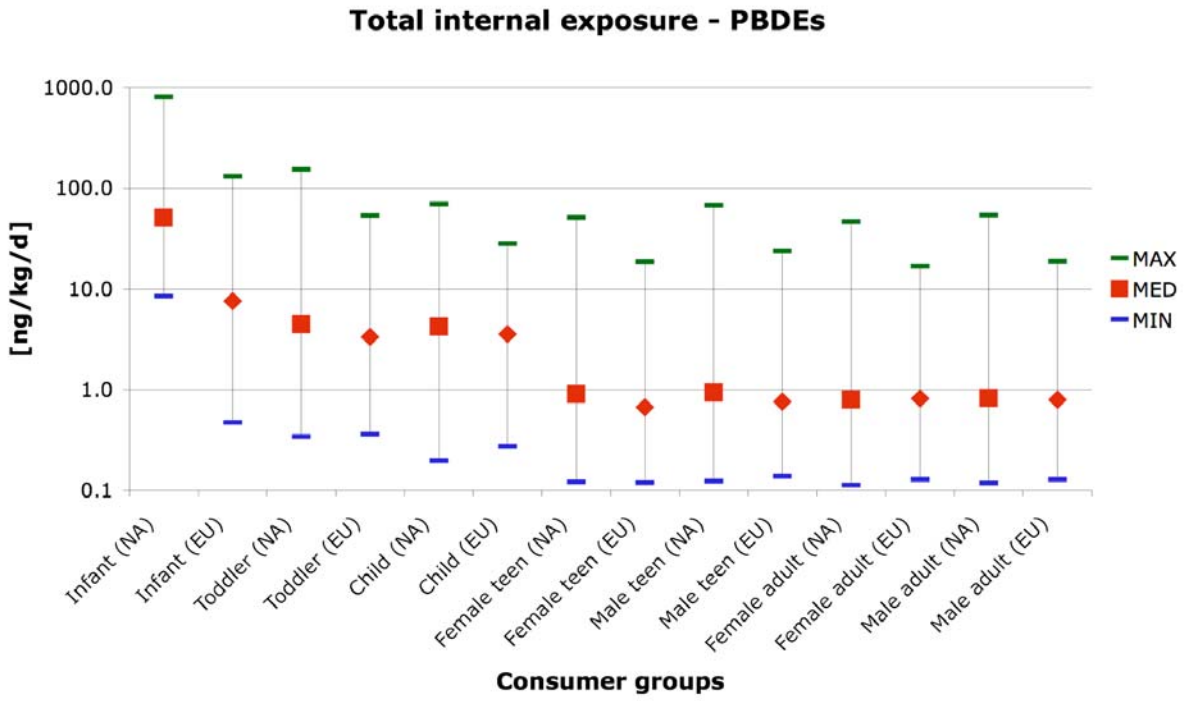

Fig. 1: Total internal exposure to PBDEs in North America (NA) and Europe (EU)

Table 1: Contribution to total internal exposure to PBDEs of the three most important media

NORH AMERICA

Food	MIN	MED	MAX
Infant	97%	89%	60%
Toddler	69%	48%	9%
Child	91%	33%	13%
Female teen	90%	94%	11%
Male teen	90%	92%	8%
Female adult	93%	95%	10%
Male adult	88%	91%	9%

Dust	MIN	MED	MAX
Infant	2%	10%	40%
Toddler	22%	50%	91%
Child	0%	65%	87%
Female teen	0%	0%	88%
Male teen	0%	1%	91%
Female adult	0%	0%	89%
Male adult	0%	1%	90%

Air	MIN	MED	MAX
Infant	1%	0%	0%
Toddler	9%	2%	1%
Child	9%	2%	1%
Female teen	10%	6%	1%
Male teen	10%	6%	1%
Female adult	7%	5%	1%
Male adult	12%	8%	1%

EUROPE

Food	MIN	MED	MAX
Infant	85%	45%	10%
Toddler	91%	50%	10%
Child	97%	36%	17%
Female teen	95%	94%	12%
Male teen	95%	93%	11%
Female adult	96%	96%	19%
Male adult	96%	94%	15%

Dust	MIN	MED	MAX
Infant	12%	54%	90%
Toddler	6%	49%	89%
Child	0%	63%	82%
Female teen	0%	0%	85%
Male teen	0%	1%	87%
Female adult	0%	0%	78%
Male adult	0%	1%	82%

Air	MIN	MED	MAX
Infant	4%	1%	0%
Toddler	3%	1%	1%
Child	3%	1%	2%
Female teen	5%	6%	3%
Male teen	5%	6%	3%
Female adult	4%	4%	2%
Male adult	4%	5%	3%

Breast-fed infants have a relatively high internal exposure to PBDEs due to contaminated breast milk and their low body weight. Due to changes in consumption and behaviour patterns and an increasing body weight, the total internal exposure declines from infants to teenagers. The exposure to PBDEs of teenagers and adults varies only little, as their behaviour and consumption patterns do not differ much from each other and their body weights are in the same range.

The preliminary results we present here do not reflect significant differences in consumer exposure to PBDEs in North America and Europe. We expected higher exposures to PBDEs in NA compared to EU for all consumer groups as it is reflected by measurements of PBDEs in human blood and milk. We could only show significant differences for infants caused by higher PBDE concentrations in breast milk of North American women compared to European mother's milk. A likely explanation for the missing differences between our exposure estimates for NA and EU is the fact that we used several studies from England (indoor dust and air) to calculate the exposure. As England had fire regulations and use patterns of PBDEs that were comparable to NA the measured concentrations in contact media are also in a comparable range.

Due to the high variability of dust consumed (0 to 300 mg/d) and high maximum concentrations in house dust, the maximum scenarios are dominated by dust intake. The minimum and medium scenarios are dominated by food intake primarily due to relatively high PBDE concentrations in fish and meat and the use of the same consumption pattern for minimum, medium and maximum scenarios (no variability as in dust consumption).

In a second phase of our study we will verify the preliminary estimates to get a comprehensive picture of consumer exposure to PBDEs in North America and Europe. Moreover, we will include further

exposure pathways such as exposure to PBDEs from particles adhered to the skin or transfer of PBDEs from retail products into the human skin.

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