Observations on the quantitative links between PBDE uses, emissions and environmental measurements in Europe

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Introductory remarks

A European consumption and atmospheric emissions inventory for pentabrominated diphenyl ethers (PeBDEs) was derived for the period 1970-2000. It was estimated that a total of 3,000-5,000 metric tonnes (t) of PeBDEs were produced in Europe during this period, with a further 9,000-10,000 t imported in finished articles. Their major stocks were predicted to be in polyurethane (flexible) foams, with up to 30% in cars, more than 10% in furniture foam and the rest in textiles, building material, packaging and solid applications. Release of PeBDEs from treated products into environmental media were estimated, with a focus on atmospheric inputs via volatilisation from their use in cars, upholstered furniture, textiles, television sets and personal computers. Different emission factors were used to derive different emission scenarios. A peak in atmospheric emissions of between 23 and 31 t of BDE-47 was estimated to have occurred around 1997, with a decline of ~20% to 2000.

PBDEs are mainly used to flame retard consumer products. The PeBDE product mix is added to both flexible and solid polyurethane (PUR) foams. Flexible foams are used in car interiors (e.g. in headrests etc.), furniture, carpets, mattresses and pillows, whilst solid PUR is used as an elastomer in various casings. In the UK, for example, ~120,000 t of PUR is produced annually, with 30% used in furniture, 18% in vehicles, and other uses in textiles and bedding. The total European PUR production was around 2.3 million t in 1998. Other uses of PeBDEs include the flame retarding of electrical appliances, such as personal computers (PCs) and television sets, and packaging. However, it has been estimated that 95% of the stock of PeBDEs resides in flexible PUR foams.

Consumption

To estimate the historical consumption of PeBDEs in Europe, our study used historical global Br production statistics. The percentage of the world Br market attributable to BFRs was then estimated. It has been suggested that PBDEs constituted 26% of the European market for BFRs in 1996, decreasing to 11% by 1999. PeBDE production represented ~10% of the total PBDE market in Europe in the early 1990s, decreasing to about 2.5 % (~210 t) in 1999. The total PeBDE consumption was calculated when adding the imports as provided by several sources, leading to different consumption scenarios using different assumptions/ literature sources.

Estimated emissions

The study estimated the atmospheric loading of this chemical class via volatilisation from products in use. A product lifetime of 10 years was suggested to account for current stocks. In order to calculate the emissions to air, the study followed three different approaches, namely emission factors based on vapour pressure, octanol-air partition coefficients and from direct measurements of PeBDE emissions from PUR foam. A "high" and "low" 1970-2000 emission estimate for BDE-47 can be seen in Figure 1. The year of peak emissions was projected to be 1997 and the peak amount 23-31 t.

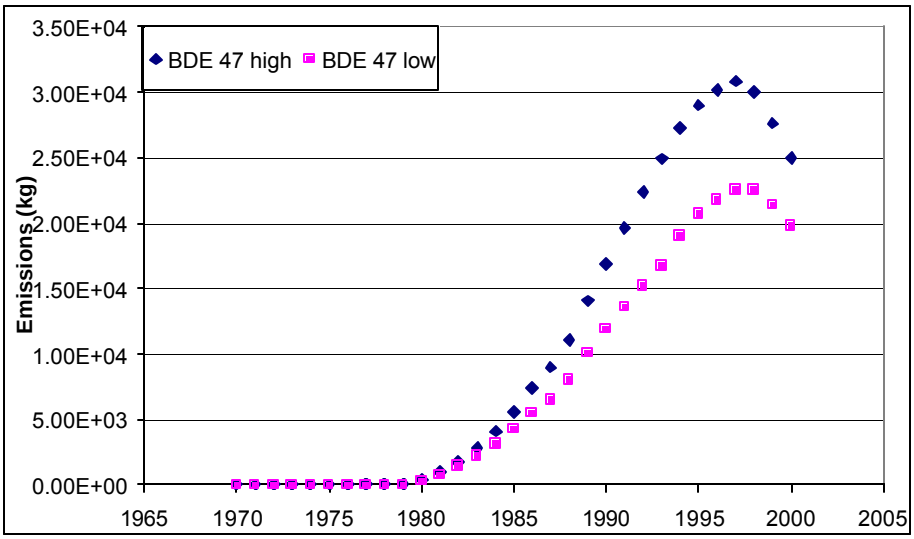

Figure 1. Historical BDE-47 emission patterns derived using the V_P approach

Comparisons with long-term environmental monitoring data revealed that the time trends of human blood and milk concentrations follow similar patterns to the generated emissions, whilst sediment core levels increase more slowly, probably because they respond to a mix of atmospheric and catchment inputs (Figure 2). Particularly noteworthy are the matched timing of the peak year and the rapid decline noted in the Swedish human milk. The Norwegian blood data suggest a levelling off between 1995 and 1999. National differences in trends and levels are to be expected, because of different PBDE usage patterns and controls.

Observations and future objectives

The emissions data derived here can be used in a spatially and temporally resolved form as input data for multi-media environmental fate modelling. In this way, models can 1. Test the PeBDE emission estimates for Europe by investigating the balance between model predictions and ambient measurements; 2. Investigate the spatial patterns of selected congeners by using contrasting surrogates for PeBDE distribution throughout Europe; 3. Project atmospheric concentration declines and other future trends by running the model in a dynamic fashion for the period 1970-2010. A

European scale multi-media fate model has been developed that requires gridded emission and other environmental input (1).

An array of 'internally consistent' environmental data is now becoming available, on emissions, air, soils, vegetation and human tissues, with which to explore more fully the relationship between estimated sources, environmental loadings and trends (2-7).

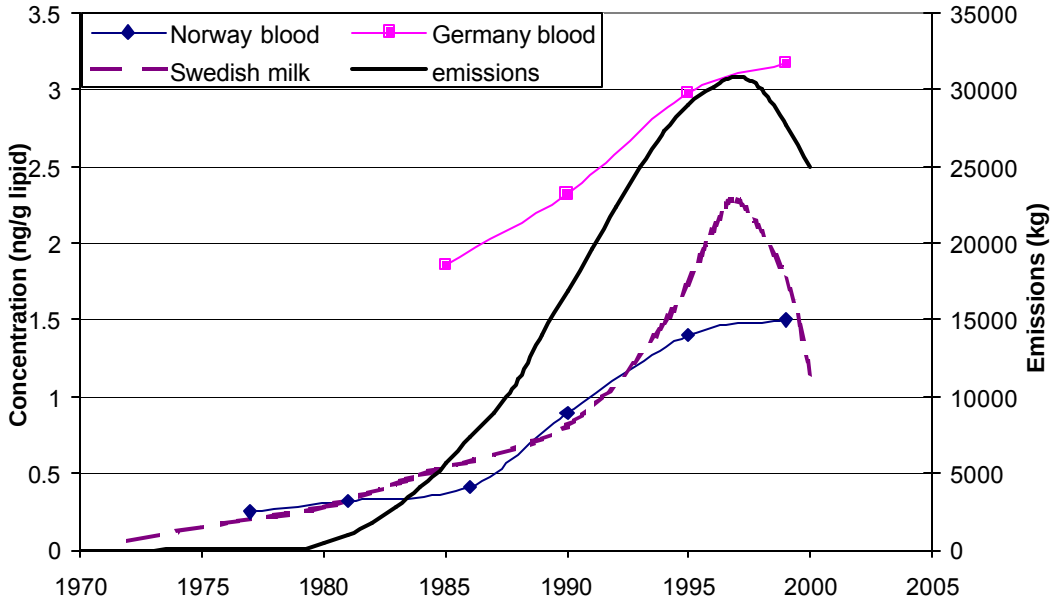

Figure 2. Comparisons between the projected emissions and measured trends in human blood and milk

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