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EXPOSURE ASSESSMENT OF DUTCH NURSING INFANTS TO BROMINATED FLAME RETARDANTS VIA BREAST MILK

R. de Winter-Sorkina, M.I. Bakker, R.A. Baumann, R. Hoogerbrugge and M.J. Zeilmaker

National Institute of Public Health and the Environment, P.O. Box 1, 3720 BA Bilthoven, The Netherlands

Introduction

Though pesticides, dioxins, furans and PCBs in Dutch breast milk have declined in the periode between 1988-1998 the result of monitoring research in Sweden has indicated that, at the same time, the levels of brominated flame retardants (BFRs) in breast milk are increasing, with concentrations doubling every 5 years[2,7]. This finding prompted the analysis of Dutch breast milk on the occurrence of PolyBrominatedDiphenylEthers (PBDEs). In practice breast milk was collected in 1998 from Dutch primiparous women on day 6 to 10 after labor and analysed on PBDEs. The measured concentrations were used as the starting point for the estimation of the exposure of nursing children to PBDEs via breast milk. In the determination of this exposure a probabilistic approach was followed, i.e. the child's PBDE intake rate was assumed to be determined by inter-individual variability of the PBDE concentration in breast milk, the milk intake rate and the infant's body weight. Exposure (mean, standard deviation, minimum, maximum, 5% percentile and 95% percentile) was assessed for breast feeding periods of 8 days and 1, 2, 3, 4, 5, 6, 7.5, and 9 months, resulting in the cumulative intake in ng per kg body weight.

Model description.

In concordance with Hoover[6] the cumulative exposure of Dutch nursing infants to brominated flame retardants (PBDEs) via breast milk is expressed as:

$$\textit{Cumulative exposure}\ (\text{ng/kg body weight}) = \int_0^T \frac{C_m \times I_m(t)}{W(t)} dt\,, \qquad (1)$$

$$C_m = C_f \times F, \qquad (2)$$

Where T is breast feeding period duration in days, C_f is the concentration of the contaminant in breast milk fat in ng/g fat, F is the fat content in breast milk in g fat/g milk, I_m is the intake of breast milk in g milk per day, W is the nursing infant body weight (bw) in kg and t is time (in this particular case time is equivalent to the age of the nursing child). The concentration of the contaminant in breast milk C_m, the intake of breast milk I_m and the nursing infant body weight W are characterised as specific probability distribution functions. The latter parameters vary with the age of a nursing infant (see below). Probability distributions were determined for 10 PBDE's congeners from 25000 random trials by Latin Hypercube sampling following equation (1).

The 108 breast milk samples were obtained from Dutch primiparous women 6 to 10 days after labor in 1998 and analysed on 11 different PBDE congeners. The BDE138 congener was not found in any of the breast milk samples in concentrations exceeding

its level of detection. Therefore no exposure calculations were carried out for this congener. A statistical summary of the concentration measurements of the remaining 10 congeners is given in Table 1. With respect to the amount of PBDE's in breast milk the concentration of PBDEs in Dutch breast milk in 1998 is comparable to that in breast milk in Sweden in the same period[2].

In calculating the exposure, the concentrations of congeners lying below the level of detection were assumed to have a value of half the value of the detection limit. In the exposure calculations the "best fit" probability density functions were used.

Breast milk intake rates are determined as a function of age following the weighted (by the number of nursing infants studied) average approach used in the Exposure Factors Handbook[5]. As shown in Figure 1 the mean breast milk intake rates and standard deviations are determined using data from for nursing infants aged 1 to 12 months. Normal distributions truncated to positive values up to maximum of 1200 g/day represent probability density functions describing breast milk intake by nursing infants. In calculation of exposure doses a positive correlation between breast milk intake and body weight of 0.56[3] is taken into account.

Table 1. Statistical summary of polybrominated diphenyl ethers (PBDEs) congener concentrations.

	No.>LOD	Minimum, ng/g fat	Maximum, ng/g fat	Median, ng/g fat	Mean, ng/g fat	Standard deviation, ng/g fat	Relative standard deviation
BDE17	10	<0.03	0.13	<0.03			
BDE28	108	0.05	0.43	0.11	0.13	0.07	0.50
BDE47	108	0.45	6.50	1.23	1.56	1.09	0.70
BDE66	36	<0.06	0.32	<0.06			
BDE85	13	<0.08	0.17	<0.08			
BDE99	108	0.17	2.70	0.40	0.53	0.40	0.76
BDE100	108	0.09	1.72	0.31	0.37	0.25	0.67
BDE138	0	<0.1	0.00	<0.1			
BDE153	108	0.33	3.88	0.91	1.02	0.52	0.51
BDE154	51	<0.08	0.26	<0.08			
BDE183	105	<0.09	1.90	0.42	0.45	0.28	0.61

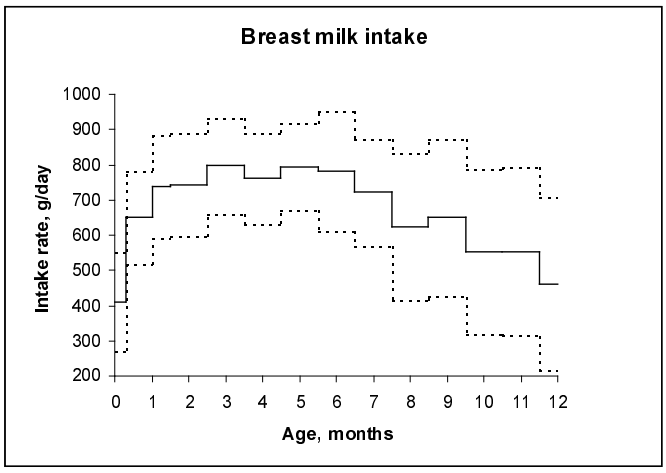

Fig. 1. Breast milk intake (mean and ranges equal to one standard deviation) by nursing infants from birth to 1 year of age.

The body weights and standard deviations of neonates at birth and at the age of 0.5 month were taken from ICRP[8]. Averaged weights and standard deviations of Dutch infants aged 1 to 9 months were Burgmeijer *et al.*[1] .

Results and Discussion.

In general the following decreasing ordering of exposure was obtained: BDE47, BDE153, BDE99, BDE183, BDE100, BDE28, BDE66, BDE154, BDE85 and BDE17.

Taking a breast feeding periods of 6 to 9 months as an example the mean cumulative exposure ranged from 1 •g/kg bw (BDE47) to 13 ng/kg bw (BDE17) for 6 months of breast feeding and from 1.4 •g/kg bw (BDE47) to 17 ng/kg bw (BDE17) for 9 month of breast feeding. The 95% percentile ranges from 2.5 •g/kg bw (BDE47) to 26 ng/kg bw (BDE17) for 6 month of breast feeding and from 3.2 •g/kg bw (BDE47) to 34 ng/kg bw (BDE17) for 9 months of breast feeding.

In the Netherlands a breast feeding period of 6 months is recommended (Lanting et al., 2002, with 18.5% of Dutch infants exclusively being breast fed up to this period). For this period Fig. 2 shows the probability distributions of exposure to BDE47, i.e. the congener with the highest concentration in breast milk.

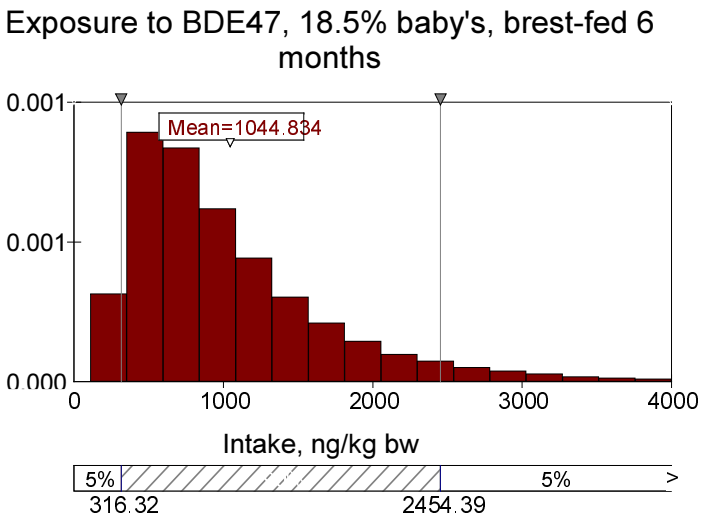

Fig. 2. Probability distribution of cumulative exposure via breast milk to BDE47 of Dutch infants exclusively breast-fed during 6 months.

As with BDE47 a rather large inter-individual variation in exposure was found for all congeners. For example, when the ratio between the 5% and the 95% percentiles of the exposure distributions was taken as a measure for inter-individual variability the following variability was calculated: 4.6 (BDE17), 5.7 (BDE28), 7.8 (BDE47), 10.9 (BDE66), 4.6 (BDE85), 9.2 (BDE99), 7.3 (BDE100), 5.1 (BDE153), 9.0 (BDE154) and 15.4 (BDE183).

The results of this study indicate that in The Netherlands PBDEs from food have accumulated in the body. As a result PBDEs are excreted in breast milk in quantities high enough to lead to considerable exposure of nursing infants to these compounds. In comparison with the exposure of adults to PBDEs from food this exposure is relative high. For example, restricting the exposure assessment to the 6 PBDE congeners which could be detected in almost all of the analysed milk samples and taking the recommended breast feeding period in The Netherlands as a reference, i.e. 6 months, it appears that the exposure of nursing infants via breast milk is higher than the exposure of adults via food calculated from total diet study (see Table 3).

Table 3. The mean daily PBDE intake of nursing children via breast milk during a breast feeding period of 6 months and the daily PBDE intake of adults via food[4].

Congener	Nursing infants exposure, ng/kg bw/day	Adults exposure, ng/kg bw/day
BDE28	0.51	0.009
BDE100	1.4	0.24
BDE183	1.8	Not determined
BDE99	2.2	0.54
BDE153	3.8	0.96
BDE47	5.8	0.70

Conclusions

In summary, nursing infants are exposed to considerable amounts of PBDEs via breast milk. This exposure, which is higher than the exposure of adults to PBDEs via food, may lead to a relatively high accumulation of PBDEs in nursing children.

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