Exposure of Americans to Polybrominated Diphenyl Ethers. Part 2. Child and Infant Exposures

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INTRODUCTION

The exposure of American infants and children to polybrominated diphenyl ethers, PBDEs, was systematically evaluated in this study. First, exposure media data on PBDE congeners were compiled. Then, intake doses pertaining to three age ranges were derived using age-specific exposure factors in combination with these concentrations. The exposure pathways evaluated included food and water consumption, inhalation, and ingestion and dermal contact to house dust. For infants, a representative profile of PBDEs in mother's milk was used in conjunction with assumptions on infant breast milk consumption to determine a daily dose to the infant. Intake doses from infancy through childhood were converted to body burdens using a simple, 1-compartment, pharmacokinetic (PK) model. As a first approximation on the impact to an infant's and young child's body burden, total PBDEs were modeled as though it were a single compound. The key PK parameters of PBDE dissipation half-life in the body and body lipid reservoir varied over time. While simplistic, the modeled body burdens of the infant and young child were higher than adult body burdens: they were in the hundreds of ng/g lipid weight (lwt), while adult body burdens are under 100 ng/g lwt. Only one study could be found which included a 5 year-old and an 18-month old, and these children similarly had body burdens in the hundreds of ng/g lwt range.

METHODS

Part 1 provided an overview of the approach for determining intake doses, and a tabular summary of the exposure media concentrations used in this exercise. These media concentrations are combined with exposure factors for food/water ingestion, inhalation, and house dust dermal contact/ingestion pathways to arrive at a total dose. Exposure factors for three age ranges of children, 1-5, 6-11, and 12-19, are provided in Table 1, along with the adult-specific factors for comparison.

Using the profile of PBDEs in mother's milk that was shown in Part 1, the dose to the infant via breastfeeding was modeled as the product of, $C * f * IR$, where C is the concentration in milk fat (ng/g lwt), f is the fraction of fat in breast milk, and IR is the ingestion rate of breast milk (g whole weight/d). The rate of ingestion of mother's milk and the fraction of fat in the mother's milk were assumed to be constant over the duration of breast-feeding, which will be 1 year in this exercise. Lorber and Phillips (2002) assumed IR = 800 g/d and f= 0.04, and these values will be used here. Given the total PBDE concentration of 95.1 ng/g lwt in mother's milk (see Part 1), the total dose to infants is 3043 ng/day. Assuming an average body weight of 10 kg for an infant during the 12 months of breast-feeding, a dose is calculated as 304 ng/kg-day.

Infant impacts from ingestion of PBDEs through breast milk and children's body burdens were handled in a different manner than adult body burdens modeled in Part 1. The approach followed mirrors that done for infant exposures to dioxins by Lorber and Phillips

(2002). Those procedures, as applied to BDEs insead of dioxins, include: 1) total PBDEs will be modeled instead of individual congeners; one half-life (variable over time as noted below) and absorption factor will be used to characterize total PBDEs; 2) the dynamic solution to the simple 1-compartment, pharmacokinetic (PK) model will be used instead of the steady state solution, to be able to characterize temporal changes in dose, dissipation half-life, body lipid fractions, and body weight, and 3) the dissipation half-life for total PBDEs in infants will be more rapid than had been assumed for individual congeners for adults.

Lorber and Phillips (2002) cited the pharmacokinetic modeling work of Kreuzer et al (1997) in their assignment of the overall dissipation rate for dioxin TEQs from infancy into childhood. Kreuzer et al (1997) found that the overall dissipation rate of 2,3,7,8-TCDD in infants was driven by the non-metabolic process of fecal elimination. Specifically, the overall dissipation half-life of 2,3,7,8-TCDD was modeled to be about 0.4 yrs at birth, compared to 5 years or more at adulthood, because of the magnitude of lipid loss in fecal elimination in infants. Since 2,3,7,8-TCDD accumulates in lipids (as do the PBDEs), the rapid loss of lipids via fecal elimination results in a comparable rapid loss in 2,3,7,8-TCDD. Lorber and Phillips (2002) assumed this rapid a half-life at birth, rising to a half-life more in the range of 5 years by 18 years of age. This same rapid half-life profile will be used here, rising to an overall representative half-life of 6 years by age 11. Lorber and Phillips (2002) also assigned temporally varying body lipid contents and body weights; see Table 2. Absorption of PBDEs will be assumed to be 80% (absorption fraction = 0.8), and the initial body burden at birth will be 65 ng/g lwt, similar to the adult total body burden from blood measurements.

RESULTS

1) The total dose for the three age ranges of children were: 751 ng/day for the 1-5 age range, 439 ng/day for the 6-11 range, and 536 ng/day for the 12-19 age range. On a body weight basis, the doses are 50.1 ng/day for ages 1-5 (assuming 15 kg bw), 14.6 ng/kg-d for 6-11 (30 kg), and 9.2 ng/kg-d for 12-19 (58 kg). These compare with the estimate of 7.3 ng/kg-d for adults derived in Part 1. The much higher dose for the child age 1-5 was due to the doubling of soil/dust ingestion from 50 mg/day to 100 mg/day.

2) The final results of the infant body burden impacts from a year of breast feeding are shown in Figure 1. Also shown there is the impact on body burden had an overall half-life of 6 years been assumed from birth. With the assumption of more rapid elimination earlier in life, the infant body burden rises to about 250 ng/g lwt at age 1 and stays in the 200-250 ng/g lwt through age 5, at which point it begins to drop, to only dip below 100 ng/g lwt by age 19. If total PBDEs had an overall half-life of 6 yrs from birth on, than the body burden would rise to 350 ng/g lwt by age 1, and continue to rise to about 450 ng/g lwt by age 5, only then to slowly dissipate to levels below 100 ng/g lwt by age 19.

The validity of these predictions cannot be verified because of the lack of data in the literature. However, there is one study of four individuals within a family in California. Fischer et al (2006) present data on the two parents, a 35 and 37 year-old, a 5 year-old daughter, and an 18-month old son in Sep and Dec of 2004. The sum of BDEs 47, 99, 100,153, 154, and 209 in the parents ranged between 64 and 147 ng/g lwt in the two sampling dates, but the concentrations in the children were much higher. The 5 year-old had

concentrations of 237, 239/249 ng/g lwt of the 5 congeners for the Sep and then Dec samples (the last two, 239/249, were duplicates of the same Dec sample). The toddler had the highest concentrations of all: 418 and 488/476 for the five congeners. Discounting laboratory error, the authors attribute the higher concentrations in the children to exposure to house dust, and the highest levels in the toddler were attributed to consumption of breast milk by Fisher. These high measurements in children support the simple PK modeling done here, but are not sufficient to verify it. Body burden measurements in children remain an uncertainty, although the modeling and this single family provide evidence that body burdens in children could be higher than adults; they could range into the hundreds of ng/g lipid weight.

Disclaimer

The views expressed in this article are those of the authors and do not necessarily reflect the views or policies of the U.S. Environmental Protection Agency. Mention of trade names or commercial products does not constitute endorsement or recommendation for use.

Bibliography

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2. Lorber M, L Phillips. 2002. *Env Health Persp* 110: A325-A332.
3. Fischer D, et al. 2006. *Env. Health Persp* 114: 1581-1585.

Table 1. Exposure pathways and factors for the PBDE intake dose estimates for three age ranges of children, compared with adult exposure factors.

Exposure Factors; Units	Adult	Ages 1-5	Ages 6-11	Ages 12-19
body weight, kg	70	15	30	58
soil Ingestion, mg/d	50	100	50	50
soil dermal contact, mg/d	12	2.2	3.2	11
inhalation, m^3/d	13.3	7.5	12	14
fraction indoor	0.875	0.792	0.792	0.875
water ingestion, l/d	1.4	0.69	0.79	0.97
milk ingestion, g/d	175	348	357	308
dairy ingestion, g/d	55	103	88	77
Egg ingestion, g/d	16.8	11.25	12.3	13.9
beef ingestion, g/d	49.7	21	33	48.1
pork ingestion, g/d	15.4	7.2	10.5	15.7
poultry ingestion, g/d	35	16.5	26.1	33.6
other meat, g/d	24.5	16.5	20.7	24.4
freshwater/marine fin fish, g/d	11.6	3	3.8	4.5
freshwater/marine shellfish, g/d	3.8	1	1.2	1.5

Table 2. Pharmacokinetic parameters for modeling infant and early childhood body burdens of PBDEs.

Time after birth	PBDE half-life, yr	Body lipid fraction	Body weight, kg	Total PBDE dose, ng/day
0	0.40	0.14	3.3	3043
1 mon	0.50	0.16	4.3	3043
2 mon	0.60	0.18	4.6	3043
3 mon	0.70	0.20	6	3043
4 mon	0.75	0.22	6.7	3043
5 mon	0.80	0.23	7.4	3043
6 mon	0.85	0.25	7.9	3043
7 mon	0.90	0.25	8.4	3043
8 mon	0.95	0.24	8.8	3043
9 mon	1.00	0.24	9.2	3043
10 mon	1.05	0.23	9.4	3043
11 mon	1.10	0.23	9.8	3043
12 mon	1.15	0.23	11.3	3043
1 yr, 3 mon	1.30	0.22	11.7	751
1 yr, 6 mon	1.50	0.21	12.5	751
1 yr, 9 mon	1.70	0.20	12.9	751
2 yr	2.00	0.20	13.3	751
3 yr	2.50	0.18	15.6	751
4 yr	3.00	0.16	17.6	751
5 yr	3.50	0.15	19.7	751
6 – 11 yr	4.00 – 6.00	0.15 – 0.13	24 – 41	439
12 – 19 yr	6.00	0.13 – 0.15	41 - 64	536
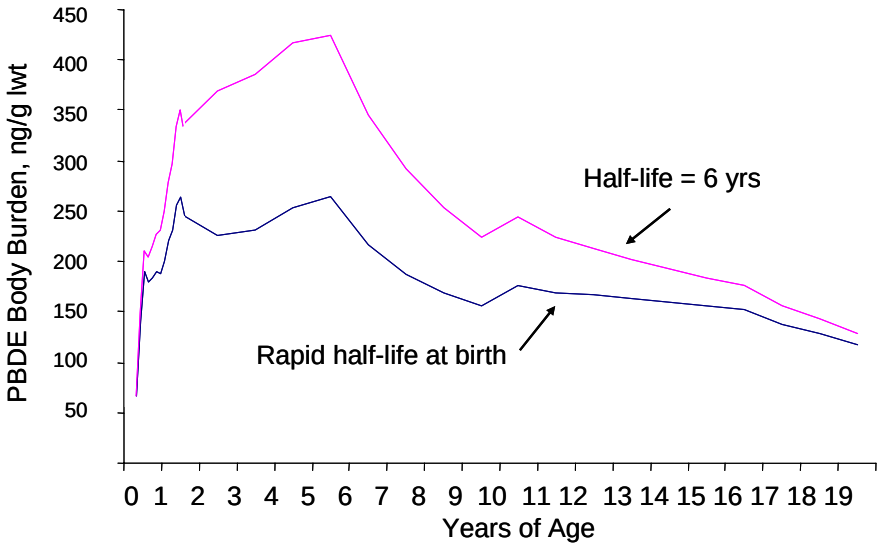
Figure 1. Modeled infant and childhood body burdens of PBDEs.