Exposure to PCBs, PCDDs and PCDFs through breast milk compared with long-term dietary exposure

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Introduction

Polychlorinated biphenyls (PCBs), and polychlorinated dibenzo-para-dioxins (PCDDs) and polychlorinated dibenzo-furans (PCDFs), known as dioxins, are widespread and persistent environmental pollutants which resulted in contamination of the human food chain (1). The general population is exposed to PCBs and dioxins mainly through the food chain, especially dairy products, industrial oils, fish and meat (2, 3). Usually more than 90% of the total daily human exposure to PCBs and dioxins is made up of oral intake from food, whereas other routes e.g. water, air and soil normally contribute to less than 10% of total exposure (2, 3). Most of the PCB and dioxin congeners will be absorbed and eventually stored in fat tissue. The human fetus is exposed to PCBs and dioxins through placental transport (4-6) and higher quantities of these compounds are transferred to the infant during breast-feeding (7,8). The concentration of these compounds in breast milk is dependent on the maternal PCB and dioxin body burden. This body burden is the result of accumulation over many years combined with the long half-life for most congeners, ranging from 7-10 years (9,10).In this extended abstract a model is described representing the cumulative intake of PCBs and dioxins during breast-feeding versus the cumulative dietary intake after breast-feeding, until 25 years of age.

Methods

From 1990-1992, 207 mother-infant pairs were recruited in Rotterdam and surroundings, an industrialized and densely populated area in the Western part of the Netherlands. Infants; 1st or 2nd, born at term, Caucasian, without perinatal complications, were included for follow-up from birth until preschool age. To study the effects of perinatal exposure to PCBs and PCDD/Fs, two groups of women were included, a group of women who intended to breast-feed their child for at least 6 weeks (breast-fed group = BF) and a group of women who

intended to give formula (formula-fed group = FF) directly after birth. The study design and chemical analysis have been described elsewhere (11,12).

Cumulative TEQ intake of PCBs and dioxins during breast-feeding (0-1 year).
In the second week after delivery, a 24 hour representative sample of breast milk was collected from breast-feeding mothers. Breast milk samples were analyzed for the seventeen most abundant 2,3,7,8 substituted PCDD and PCDF congeners and three planar PCB congeners (IUPAC Nos 77, 126 and 169).To express the total toxic potency of dioxins and dioxin-like PCBs, the toxic equivalent factor (TEF) approach was used according to Safe (13) and WHO, respectively (14). The cumulative TEQ intake during breast-feeding was calculated based on the following assumptions:
(1) From birth until 6 months of age (26 weeks) an infant will drink an average of 800 ml/d (15-17); from 6 to 9 months (27-39 weeks), 500 ml/d (28), and from 9 months (> 39 weeks) until cessation of breast feeding 400 ml/d.
(2) Breast-feeding period (T) was defined as the number of weeks during which the infant was predominantly breast-fed, as reported by the mother.
(3) Literature data indicate that 95% (=0.95) of all PCBs and dioxins are absorbed in the digestive tract (18, 19).
(4) Several studies have shown that PCB and dioxin body burden of a mother during breast-feeding decreases by 20% per three months and therefore we used this percentage to calculate a weekly decrease of 1.7% in PCB and dioxin concentration in breast milk of each breast-feeding mother (20, 21).
The cumulative intake (I) of PCB-TEQ and dioxin-TEQ during breast-feeding was calculated with the method of integration according to the volume of breast milk (V) consumption varying over time (6-26 weeks, 27-39 weeks, > 39 weeks).
The following equation was used to calculate the cumulative planar PCB- and dioxin-TEQ intake (I) during the whole breast-feeding period:

$$I \text{ (pg)} = 0.95 \times V \text{ (ml)} \times \text{milk fat (g/ml)} \times [\text{TEQ}] \text{ breast-milk (pg/g milk fat)} \times {}_0\!\int^T e^{-0.017t} dt$$

Cumulative TEQ intake of PCBs and dioxins during the preschool period (1-5 years)
At the age of 3.5 years, the primary person in care of the child, usually the mother, was asked to fill out a semi-quantitative food questionnaire (FQ) developed by the Division of Human Nutrition and Epidemiology, Agricultural University Wageningen, the Netherlands. The FQ was designed to assess dietary TEQ intake of three planar PCBs (IUPAC Nos 77, 126 and 169) and seventeen 2,3,7,8 chlorine substituted PCDDs and PCDFs, as well as energy, fat, carbohydrate and protein intake in preschool children. The daily intake of PCB-TEQ and dioxin-TEQ was determined by calculating the TEQs of three planar PCBs and seventeen 2,3,7,8-chlorine substituted dioxins, in each food item (13, 14) using reference data for food products provided by the National Institute of Public Health and the Environment (RIVM) (3, 22). Intake of energy, fat, protein and carbohydrate were calculated using the Dutch Food Database 1993 (23). Daily total-TEQ intake was defined as the sum of planar PCB-TEQ and dioxin-TEQ intake in picogrammes per day (pg/d). The cumulative intake (I) of dioxin-TEQ and planar PCB-TEQ from 1-5 years for boys and girls was calculated from the mean total-TEQ and mean fat intake per day estimated from the FQ.

$$I \text{ (pg)} = 0.95 \times \text{fat intake (g)} \times [\text{TEQ}] \text{ (pg/g fat)} \times 365.25 \text{ days} \times n \text{ years (5 years)}.$$

Cumulative TEQ intake from childhood until adulthood (6-25 years).
The cumulative TEQ intake from 6-25 years of age was calculated based on data from the National Institute of Public Health and the Environment (RIVM) *(22)* and the National Food Consumption Survey (FCS, 1992) *(24)*. Median intake, estimated from RIVM data in the Dutch population, of planar PCB-TEQ, was 70 pg/day; for dioxin-TEQ, this was 65 pg/day yielding a total-TEQ intake of 135 pg/day *(25)*. This value in combination with a mean daily fat consumption of 92 g in the Dutch population derived from the FCS *(24)* yields a mean daily TEQ consumption of 1.47 pg/g fat. Since fat intake changes by per age and gender the cumulative TEQ intake (I) for men and women was calculated for each 5-year age-group using the mean daily TEQ consumption of 1.47 pg/g fat and the mean daily fat consumption for each age-group.
I (pg) = 0.95 X Fat intake (g) X 1.47 pg TEQ/g fat X 365.25 (days) X n years (5 years).
The mean daily TEQ intake for males and females and the mean daily TEQ intake per kg body weight (BW) at different ages was calculated. Mean BW standards of healthy Dutch children and adolescents were used as reference data (26).

Results

The mean daily TEQ intake per kg BW per day for infants receiving breast milk for 6 months was calculated according to the formula presented in the methods. For boys this was 112 pg TEQ/kg BW and for girls this was 118 pg TEQ/kg BW, which is about 50 times higher than the mean daily TEQ/ kg BW from 20-25 years (2.3 and 2.0 pg TEQ/kg BW, respectively). The mean daily TEQ intake is 6.8 pg TEQ/kg BW during preschool age (1-5 years), which is 3 times higher than in adults (20-25 years).
The estimated cumulative TEQ intake for infants who were breast-fed for 6 months as a proportion of total dietary TEQ exposure until 25 years was calculated. The total cumulative TEQ intake over a 25 year period is 1.38 µg in men and 1.16 µg in women who were breast-fed for 6 months during infancy. The TEQ intake during 6 months of breast-feeding accounts for 12 % of the relative total TEQ intake during 25 years in males, and 14 % in females (Figure).
After breast-feeding, at preschool age (1-5 years), the mean ± SD daily PCB-TEQ intake was 61 ± 23 pg in boys and 57 ± 21 pg in girls (NS). The mean daily dioxin-TEQ intake was 48 ± 16 pg and 45 ± 14 pg, respectively (NS). Four percent of children below 5 years of age exceed the Tolerable Daily Intake (TDI) of 10 pg TEQ/kg BW day. Dairy products contributed 43 % to PCB-TEQ intake and 50 % to dioxin-TEQ intake. Meat and meat products contributed 14 % respectively 19 % to PCB-TEQ and dioxin-TEQ intake, and processed foods 23 % and 15 %, respectively. The contribution of fish was much lower (11% and 5 %, respectively).

Discussion

We estimated the cumulative PCB- and dioxin-TEQ intake from birth until 25 years of age. According to our model, breast-feeding for 6 months accounts for 12 to 14 % of the dietary exposure until 25 years of age. These values are in the order of magnitude as model calculations by other authors *(21, 27)*. The daily TEQ intake per kg BW for infants breast-fed

during 6 months is approximately 50 times, and for children until 5 years of age three times as high as in adults. The numbers presented should be regarded as an indication rather than as exact values. Although some model calculations of PCB and dioxin body burden and infant exposure through breast milk have been published (21, 27) the cumulated PCB and dioxin intake from infancy until adulthood has not been quantitatively assessed previously. It should be noted that the cumulative intake as estimated in this study is not identical to body burden, since losses by excretion and the long half-lives of different PCB and dioxin congeners are not taken into account. In conclusion, our results show that breast-feeding makes up for a relatively small proportion (12 and 14 %) of the cumulative dietary PCB and dioxin exposure until reproductive age for males respectively females. Furthermore, we find that the main food sources of PCBs and dioxins after weaning in young children are dairy products, processed foods, and meat and meat products. Combined with our earlier reports and results from other studies showing that disturbances in growth and development in children are mainly related to in utero exposure, rather than lactational exposure to PCBs and dioxins, it is concluded that strategies should be directed towards reducing PCB and dioxin intake through the food chain at all ages and not at discouraging breast-feeding.
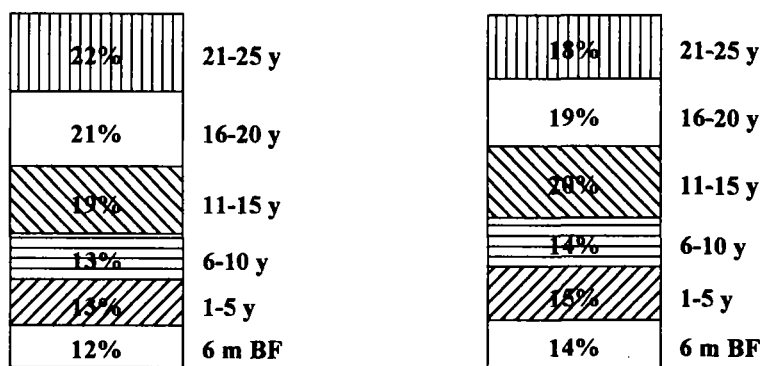
Acknowledgments

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Relative total TEQ intake

6 months BF until 25 years

MALES		FEMALES	
22%	21-25 y	18%	21-25 y
21%	16-20 y	19%	16-20 y
19%	11-15 y	20%	11-15 y
13%	6-10 y	14%	6-10 y
13%	1-5 y	15%	1-5 y
12%	6 m BF	14%	6 m BF

MALES　　　　　　　**FEMALES**