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ScienceDirect
Environment International 33 (2007) 239–245
ENVIRONMENT INTERNATIONAL
www.elsevier.com/locate/envint

Levels of polybrominated diphenyl ethers (PBDEs) in breast milk from central Taiwan and their relation to infant birth outcome and maternal menstruation effects

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Received 29 July 2006; accepted 25 September 2006
Available online 31 October 2006

Abstract

In utero exposure to polybrominated diphenyl ethers (PBDEs) reduces the number of ovarian follicles in rat females and causes permanent effects on rat males. Little data have been gathered on the associations between PBDEs exposure and birth outcome and female menstruation characteristics in both epidemiological and animal studies. The aim of this study was to examine how PBDEs in breast milk are associated with infant birth outcome and maternal menstruation characteristics. Study participants were healthy women recruited from central Taiwan between December 2000 and November 2001. Twelve congener levels of PBDEs (BDE-17, 28, 47, 66, 85, 99, 100, 138, 153, 154, 183, 209) in 20 breast milk samples were measured by gas chromatography with high resolution mass spectrometer. The mean level of PBDEs in breast milk was 3.93 ± 1.74 ng/g lipid. The estimated PBDE daily intake for a breastfed infant was 20.6 ng/kg b.w./day after delivery. After maternal age, pre-pregnant BMI, and parity were adjusted, increased PBDEs in breast milk was related with decreased birth outcome, particularly for birth weight and length, chest circumference, and Quetelet's index of infants. No significant differences in PBDEs were found between the two groups of menstrual cycle length higher and lower than 30 days after we adjusted for maternal age, pre-pregnant BMI, and parity. In utero exposure to low doses of PBDEs may result in lower birth weight and short or birth length. Our findings are limited based on the low doses of PBDEs and the small sampling size.

Keywords: Polybrominated diphenyl ethers; Breast milk; Breastfeeding; Infants; Reproductive effects; Menstruation; Birth outcome; Birth weight; Daily intake

1. Introduction

Human exposure to persistent organic pollutants (POPs) such as polybrominated diphenyl ethers (PBDEs) has been a raising global concern (Darnerud et al., 2001). The industrial chemicals of PBDEs are lipophilic endocrine disruptors (Legler and Brouwer, 2003) with high resistance to biodegradation in the environment (de Wit, 2002). From previous studies (Päpke, 1998; Norén and Meironyté, 2000), body burden of dioxins, polychlorinated biphenyls (PCBs), and organochlorine pesticides (OCPs) has obviously decreased in reports from several developed countries during these two decades. In contrast, PBDE levels in human specimens show significant increases with the time of sample collection (Norén and Meironyté, 2000; Thomsen et al., 2002; Sjödin et al., 2004).

The congeners of PBDEs are widespread in the global environment from the manufacturing or waste disposal processes (de Wit, 2002; Ikonomou et al., 2002). PBDEs have been found in dust (Wilford et al., 2005), fish (Christensen et al., 2002), vegetables (Ohta et al., 2002), aquatic mammals (de Boer et al.,

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doi:10.1016/j.envint.2006.09.013

Table 1
PBDE levels in the environment and the biota from Taiwan (Peng, 2002)

Compounds	BDE-28	BDE-47	BDE-99	BDE-100	BDE-153	BDE-154	BDE-183	PBDEs
Flue gas from MSW[a]	18.0[b]	43.3	28.4	7.44	0.39	0.74	0.40	98.8
Incinerator, $n=7$ (ng/m^3)	(6.48–32.3)[c]	(34.0–51.6)	(11.5–45.2)	(3.89–9.67)	(0.27–0.51)	(0.42–1.06)	(0.33–0.52)	(59.3–141)
Flue gas from EAF[d]	12.8	32.0	14.6	2.01	2.35	2.19	1.65	67.6
Incinerator, $n=3$ (ng/m^3)	(5.42–19.3)	(20.9–50.4)	(7.69–19.4)	(1.11–2.64)	(1.38–3.24)	(1.24–2.91)	(0.93–2.20)	(47.0–95.6)
Fly ash from MSW	4.12	66.6	60.9	17.9	13.5	9.75	16.6	189
Incinerator, $n=8$ (pg/g)	(1.0–10.0)	(35.0–160)	(22.0–175)	(6.0–40.0)	(4.0–29.0)	(2.0–24.0)	(5.0–39.0)	(85.0–409)
Soil from Taipei	8.69	43.6	25.5	6.25	17.3	14.3	28.0	144
$n=8$ (pg/g)	(0.5–40.0)	(10.0–163)	(5.0–54.0)	(2.0–11.0)	(5.0–72.0)	(4.0–67.0)	(11.0–63.0)	(54.0–333)
Fish from Kao-Ping river	0.21	5.24	0.32	0.86	1.30	5.63	0.30	13.9
$n=7$ (ng/g lipid)	(0.066–0.59)	(1.02–11.2)	(0.15–0.61)	(0.36–1.66)	(0.43–2.32)	(1.70–9.62)	(0.10–0.50)	(4.57–25.0)

[a] Municipal Solid Waste.
[b] Mean.
[c] Range.
[d] Electric Arc Furnace.

1998), and territorial mammals on land including humans (Darnerud et al., 2001; Mazdai et al., 2003). Few reports in Taiwan have focused on PBDE levels in the environment or in the biota. The levels of PBDEs in the ambient air collected near metal recycling plants were found to range from 23 to 53 pg/m^3 in Taiwan in 1992 (Watanabe et al., 1992). The PBDE congeners found in the air, soil, sediment, and fish samples in Taiwan are presented in Table 1 (Peng, 2002). To my knowledge, the data on human exposure to PBDEs has been limited in Taiwan until now. The Taiwanese Environmental Protection Administration (EPA) has legislated to ban the use of PCBs and OCPs and to meet strict standards of dioxins emission, but the use of PBDEs is not restricted in Taiwan.

Little is known about the adverse human health effects of PBDEs, even though they have been widely used for two decades. PBDEs and PCBs may induce similar carcinogenic, neurotoxic, reproductive, and immunotoxic effects due to the similarity of their chemical structure and lipophilic properties. Several reports have shown hepatotoxicity, embryotoxicity, thyroid, and behavioral effects in animal studies (International Program on Chemical Safety, 1994; Darnerud et al., 2001; Zhou et al., 2001; McDonald, 2002). Sanderson et al. (1996) suggested that PBDEs were weak agonists of the Ah receptor, in spite of certain structural similarities to dioxins. In recent in-vivo or in-vitro studies, high doses of PBDEs could be inducible to increasingly eliminate thyroid hormones (i.e., thyroxin) (Zhou et al., 2001), to bind with thyroid hormone receptors and transporter proteins (i.e., transthyretin) (Meerts et al., 2000), to cause changes in spontaneous behavior and impairment of learning and memory in mice and rats exposed in utero or postnatally (Eriksson et al., 2001; Viberg et al., 2003). Although few epidemiological studies have been conducted on human exposure to PBDEs, these pollutants are still of global concern due to their adverse health effects on the neurodevelopmental, reproductive, developmental, and endocrine systems, as well as causing cancers in high-dose in-vivo animal studies.

Breast milk is one of the best human specimens for the biomonitoring of PBDEs because it can reflect the maternal body burden and infant's postnatal exposure. Very little has been reported on the in-vivo PBDEs effects for female reproduction and birth outcome, and most of the published papers mainly deal with effects on thyroid hormone homeostasis and neurodevelopments. In the present study, the measurements of PBDEs in breast milk from central Taiwan were compared to those from other countries. We also found the association between PBDE levels and infant birth outcome (i.e. birth weight) or maternal menstruation effects (i.e. menstrual cycle length).

2. Materials and methods

2.1. Study participants

The study participants were selected from the cohort of the dioxin survey described previously (Chao et al., 2004). Subjects were healthy pregnant women recruited from a medical center in the suburban area of Taichung, located in central Taiwan, from December 2000 to November 2001. A well-trained research interviewer collected interview data at obstetric clinics during routine health check-ups. All of the participants answered a detailed questionnaire concerning maternal age, maternal weight before pregnancy, maternal height, smoking and dietary habits, drinking alcohol, medical and pregnancy history, and menstruation characteristics. The demographic characteristics of newborns were measured after delivery, including birth weight, birth length, gestational age, head and chest circumference, and the assessment of Apgar score in 1 and 5 min. Of those recruited, approximately 80% of the invited subjects ($n=760$) were ultimately enrolled in our study. 176 women were further selected due to compliance with the following criteria: minimum resident time of 5 years in the sampling area without a history of PCB poisoning, supply of sufficient breast milk samples (>60 ml), and eagerness to strictly obey our protocol to prevent contamination. Finally, 20 breast milk samples were randomly selected from 176 milk samples for further chemical analyses.

The study protocol was reviewed by the Human Ethical Committee of the National Health Research Institutes (NHRI) in Taiwan. Ethical standards formulated from the Helsinki Declarations of 1964 and revised in 2000 were followed. Each of the participants provided informed consent after receiving a detailed explanation of the study and potential consequences.

2.2. Samples collection and materials

The procedure for collecting breast milk was previously described (Chao et al., 2004). A mother collected her milk in a chemical-free bottle and froze it in the refrigerator at home. The milk samples were immediately transported to the laboratory in NHRI and kept frozen at −20 °C when mothers telephoned us that the samples had been collected between 30 and 50 ml in each bottle. The milk samples of 25 ml were shipped frozen to the ERGO laboratory in Germany for chemical analysis. Eleven native PBDE standards of ^{12}C-labeled BDE-17, 28, 47, 66, 85, 99, 100, 138, 153, 154, and 183 were purchased from Cambridge Isotope Laboratories