JOURNAL OF ENVIRONMENTAL SCIENCES XX (2016) XXX–XXX

Available online at www.sciencedirect.com

ScienceDirect

www.elsevier.com/locate/jes

JES JOURNAL OF ENVIRONMENTAL SCIENCES

www.jesc.ac.cn

Accumulation of polybrominated diphenyl ethers in breast milk of women from an e-waste recycling center in China

Xinghong Li[1,*], *Yuan Tian*[1,2], *Yun Zhang*[1,2], *Yujie Ben*[1], *Quanxia Lv*[1]

1. *State Key Laboratory of Environmental Chemistry and Ecotoxicology, Research Center of Eco-Environment Sciences, Chinese Academy of Sciences, Beijing 100085, China*

2. *Department of Environmental Science and Engineering, Beijing Technology and Business University, Beijing 100048, China*

ARTICLE INFO

Article history:
Received 8 March 2016
Revised 10 October 2016
Accepted 20 October 2016
Available online xxxx

Keywords:
PBDEs
OH-PBDEs
Human milk
E-waste

ABSTRACT

Polybrominated diphenyl ethers (PBDEs) can be transferred to infants through the ingestion of breast milk, resulting in potential health risk. In this study, PBDEs, hydroxylated polybrominated diphenyl ethers (OH-PBDEs) and 2,2′,4,4′,5,6′-hexachlorobiphenyl (CB-153) in human milk from women living adjacent to e-waste recycling sites of Wenling, China, were investigated. The median level of PBDEs in samples from residents living in the e-waste recycling environment >20 years (R_{20} group, 19.5 ng/g lipid weight (lw)) was significantly higher than that for residents living in Wenling <3 years (R_3 group, 3.88 ng/g lw) ($p < 0.05$), likely ascribable to specific exposure to PBDEs from e-waste recycling activities. In the R_{20} group, most congeners (except for BDE-209) were correlated with each other ($p < 0.05$). Moreover, CB-153 showed significant association with most PBDE congeners, rather than BDE-209. The relationship indicated that most BDE congeners other than BDE-209 shared common sources and/or pathways with CB-153, *e.g.*, dietary ingestion. The correlations between BDE-209 and other congeners were different in the two groups, likely suggesting their different exposure sources and/or pathways for PBDEs. Although estimated dietary intake of PBDEs for infants via breast milk was lower than the minimum value affecting human health, the PBDE exposure of infants should be of great concern because of their potential effect on the development of neonates over long-term exposure. OH-PBDEs were not detected in the collected samples, which is in accordance with reports in published literature, likely indicating that they were not apt to be accumulated in human milk.

Introduction

Polybrominated diphenyl ethers (PBDEs) are a class of compounds containing 209 congeners. PBDEs have the characteristics of environmental persistence and liposolubility, so their bioaccumulation in environmental samples can easily occur. This bioaccumulation allows PBDEs to be biomagnified in food chains, resulting in elevated levels of these compounds in human beings. Among the commercial PBDE products, penta-, octa- and deca-BDEs are the most commonly used. To date, three commercial formulations of PBDEs have been banned or restricted in the European Union, USA and Canada. However, deca-BDE commercial mixtures are still in widespread use in commercial products and industries in China and many other developing countries in Asia (Ni et al., 2013). Exposure to PBDEs, even in low doses, was reported to have negative

* *Corresponding author*. E-mail: lxhzpb@rcees.ac.cn (Xinghong Li).

http://dx.doi.org/10.1016/j.jes.2016.10.008

effects on the brain development of animal neonates, raising concerns on potential health risks of PBDEs for humans, particularly for children (Darnerud, 2008; Fromme et al., 2016).

With the increasing demand for electronic/electrical products, the amount of electrical and electronic waste (e-waste) has rapidly increased worldwide. An estimated 20–50 million tons of e-waste are generated globally every year (UNEP, 2005), and more than 2 million tons of e-waste are dismantled yearly for metals recycling in Taizhou, a primary e-waste recycling center in China. The e-waste recycling operation in Taizhou is conducted using primitive methods, wherein workers burn piles of wires in open air to remove the coatings on metals, melt circuit boards over coal grills to extract valuable chips (Yu et al., 2006), and then carelessly discard the useless plastics left after fragmentation in the surrounding areas. These unregulated operations and weak control on e-waste products have allowed PBDEs, which have been used worldwide as flame retardants for electronic/electrical products, to be easily transferred to the surrounding environment. As a result, significantly high levels of PBDEs were detected in environmental compartments surrounding the e-waste recycling sites in Taizhou, including sediments and mudsnails (Yang et al., 2009), soil and plants (Zhao et al., 2009b), the atmosphere (Han et al., 2009), and even poultry (Liang et al., 2008). Correspondingly, high levels of PBDEs were also found in human samples taken from local residents, including hair (Zhao et al., 2008), tissue (Zhao et al., 2009a), and blood samples (Zhao et al., 2010). However, only a limited amount of data was available on PBDE levels in breast milk samples from women living in the e-waste recycling sites in Viet Nam (Tue et al., 2010) and in Taizhou, China (Leung et al., 2010). In 2005, a study was performed using five breast milk samples from the women living in Luqiao, Taizhou (Leung et al., 2010). The breast milk samples in that study were found to have a mean concentration of $PBDE_s$ (including BDE-28, -47, -100, -99, -154, -153 and -183) of 70.7 ng/g lipid weight (lw) (ranging from 4.99 to 273 ng/g lw). Although the sample size was small, the result provided evidence that primitive e-waste recycling leads to high PBDE body burdens in local residents. More information on PBDE levels in milk is required in order to assess the health risk of mothers and their infants living in e-waste recycling regions.

Hydroxylated polybrominated diphenyl ethers (OH-PBDEs) are structural analogs of PBDEs. The concern over OH-PBDEs is of particular interest since they elicit a variety of effects in exposed organisms including disruption of thyroid hormone homeostasis, oxidative phosphorylation disruption, altered estradiol synthesis, and neurotoxic effects (Meerts et al., 2001; Marchesini et al., 2008). OH-PBDEs have been found in wildlife tissues (Marsh et al., 2004; Verreault et al., 2005), and human blood (Meijer et al., 2008; Stapleton et al., 2011). To date, there are no data on OH-PBDEs in human breast milk.

It is well known that the body burden of mothers can be related to the chemical levels in breast milk (Schecter et al., 2010; Mannetje et al., 2012). Therefore, it was of great importance to elucidate the mothers' exposure pathway to chemicals in order to protect mothers and their breast-fed infants. To date, the exposure sources and/or pathways of PBDEs in humans have been considered to be diverse, *e.g.*, dust inhalation, dietary ingestion, and inhalation of air (Frederiksen et al., 2009; Ni et al., 2013). However, different from PBDEs, diet was proved to be the primary exposure source of polychlorinated biphenyls (PCBs) in adults (Fernandez-Gonzalez et al., 2015), including the population living in e-waste recycling areas (Xing et al., 2010; Song and Li, 2014). Therefore, the relationship between PCBs and PBDEs might be used to explore the contribution of dietary exposure to the body burden of PBDEs in adults (Bi et al., 2006; She et al., 2007).

Human breast milk is the most important exposure pathway to chemicals for breast-fed infants, so the concentrations of PBDEs and their structural analogs (OH-PBDEs) in the breast milk obtained from women living adjacent to e-waste dismantling sites should be an area of focus. In the present study, we measured the PBDEs and OH-PBDEs in breast milk samples from women living adjacent to the e-waste recycling sites in Wenling Town, Taizhou City, Zhejiang Province, China. Our objective was to investigate the occurrence, explore possible exposure sources/pathways, and assess the potential exposure risks of PBDEs and OH-PBDEs for breast-fed infants in e-waste recycling areas. The information will be useful for evaluating the potential health risk of chemicals from e-waste recycling activities, for future environmental planning and management strategies for e-wastes.

1. Materials and methods

1.1. *Sample area*

Taizhou is located at the middle of the coastal area of Zhejiang Province and in the southern tip of the Shanghai Economic Zone in China (28°N latitude and 122°E longitude). Dismantling operations for e-wastes in this area have been ongoing for 30 years. More than 2 million metric tons of e-wastes are processed in Taizhou annually, and 40,000 people are currently employed in the e-waste dismantling industry. The most intensive e-waste dismantling operations are performed in two towns of Taizhou, Luqiao and Wenling (Fig. 1). A large number of e-waste dismantling household workshops emerged in some villages of Wenling town because of relatively weak

Fig. 1 – Sampling location in Wenling, Taizhou, China.

Please cite this article as: Li, X., et al., Accumulation of polybrominated diphenyl ethers in breast milk of women from an e-waste recycling center in China, J. Environ. Sci. (2016), http://dx.doi.org/10.1016/j.jes.2016.10.008