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# Assessment of exposure to polybrominated diphenyl ethers associated with consumption of market hens in Guangzhou

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ABSTRACT

To evaluate contamination by polybrominated diphenyl ethers (PBDEs) in market hens and human PBDE exposure via hen consumption in Guangzhou, hens were collected and their muscle, liver, fat, blood, yolk, and ingluvies tissues were analyzed for 13 PBDE congeners. The median highest concentration of ΣPBDEs was found in the ingluvies (5.30 ng/g lw), followed by the muscle (2.53 ng/g lw), with the lowest located in the yolk (0.09 ng/g lw). The concentrations of PBDEs in the muscle tissue of market hens in Guangzhou were at medium levels compared to others reported around the world. BDE-47, −153, −99, and −183 were the predominant congeners. The daily intake concentrations of PBDEs from hen muscle were estimated to range from 0.08 to 0.31 ng/kg/day in this study, with a Hazard Quotient (HQ) below 1.0. These results suggest that the health risk of PBDEs for the general population, through the consumption of market hens in Guangzhou, was generally low. However, the intake of PBDEs via food consumption may be one major exposure pathway for the general population of Guangzhou.

## 1. Introduction

Polybrominated diphenyl ethers (PBDEs) are a class of additive flame retardants, widely used in computers, televisions, textiles, furniture, and other commercial products. There are three kinds of commercial PBDE products: penta-, octa- and deca-BDEs. PBDEs can be readily released into the environment and have been detected ubiquitously in recent years, in abiotic and biotic samples, such as water (Xiong et al., 2016), sediment (Xiong et al., 2016), air (Zhu et al., 2015), fish (Zhou et al., 2016), birds (Peng et al., 2015), and the human body (Zheng et al., 2017). Studies have shown that PBDEs can cause a wide range of adverse health effects, including endocrine toxicity, neurodevelopmental toxicity, and possible carcinogenicity (Eskenazi et al., 2013; Gascon et al., 2011). Since 2009, penta-BDE and octa-BDE have been prohibited and classed as persistent organic pollutants (POPs), whereas deca-BDE, which is mainly composed of BDE-209, is still produced and used in China (Peng et al., 2015). Furthermore, products containing PBDEs are still in use and will continue to release PBDEs into the environment through their use, waste and recycling.

Guangdong Province, particularly the Pearl River Delta (PRD), is one of the most developed regions in China. Meanwhile Guangdong Province has been the largest import and recycling center of electronic waste in the world (Ni et al., 2010). Developed industry and e-waste recycling activities have resulted in high levels of PBDEs in the environment (Zhang et al., 2013). Studies have revealed an increasing trend in the concentration of PBDEs in human blood and breastmilk over the past 20–30 years in Southern China (Chen et al., 2014).

Dietary, inhalation and ingestion of dust are the main pathways of human exposure to PBDEs (Ni et al., 2012; Wang et al., 2014). and their percentage contributions to human PBDE exposure varied between different regions, due to the differences in lifestyle, age, gender, and living environments (Chang et al., 2017; Fromme et al., 2009; Qin et al., 2011; Shi et al., 2016). Ni et al. reported food to be the main route of adult exposure to PBDEs in Shenzhen, China (Ni et al., 2012). However, studies on the dietary intake of PBDEs in China have mainly focused on fish and seafood, with few studies surrounding the consumption of chicken (Zhang et al., 2013). Available studies on PBDEs in chicken have focused mainly on e-waste recycling sites (Labunska et al., 2014; Liang et al., 2008; Luo et al., 2009). Chicken is a favorite food for residents of Guangdong and chicken consumption in Guangdong province was three times higher than in other parts of China (Luo et al., 2009). Thus, PBDE exposure of residents in Guangdong, due to chicken

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**Table 1**
PBDEs concentration in various tissues of hens from Guangzhou (ng/g lipid dry weight).

| Target compounds | Muscle | | | liver | | | Fat | | | blood | | | yolk | | | ingluvies | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | n = 25 | | | n = 9 | | | | | | | | | | | | | | |
| | mean | median | range | mean | median | range | mean | median | range | mean | median | range | mean | median | range | mean | median | range |
| BDE-17 | 0.088 | 0.11 | nd-0.25 | 0.003 | nd | nd-0.02 | 0.005 | 0.006 | 0.005–0.01 | 0.1 | nd | nd-0.45 | nd | 0.003 | nd-0.005 | 0.21 | 0.18 | nd-0.53 |
| BDE-28 | 0.11 | 0.13 | nd-0.30 | 0.005 | nd | nd-0.05 | 0.004 | nd | nd-0.02 | 0.06 | nd | nd-0.30 | nd | nd | nd-0.005 | 0.51 | 0.26 | 0.007–2.02 |
| BDE-71 | 0.18 | 0.17 | 0.09–0.30 | 0.01 | nd | nd-0.10 | 0.07 | 0.05 | 0.006–0.25 | 0.11 | nd | nd-0.91 | 0.04 | 0.02 | 0.01–0.14 | 1.5 | 0.37 | 0.01–6.40 |
| BDE-47 | 0.98 | 0.92 | 0.35–1.82 | 0.1 | 0.07 | 0.007–0.51 | 0.02 | 0.02 | 0.01–0.03 | 0.46 | 0.08 | nd-1.78 | 0.03 | 0.02 | 0.003–0.06 | 1.12 | 0.40 | 0.11–3.77 |
| BDE-66 | 0.12 | 0.12 | nd-0.44 | 0.009 | nd | nd-0.05 | 0.006 | 0.004 | nd-0.01 | 0.07 | nd | nd-0.41 | nd | nd | nd | 0.49 | 0.28 | 0.01–2.16 |
| BDE-100 | 0.15 | 0.14 | 0.09–0.31 | 0.01 | nd | nd-0.06 | 0.008 | 0.006 | nd-0.02 | 0.05 | nd | nd-0.26 | nd | nd | nd | 0.52 | 0.18 | 0.01–1.68 |
| BDE-99 | 0.18 | 0.21 | 0.05–0.39 | 0.04 | 0.03 | nd-0.09 | 0.02 | 0.02 | 0.007–0.04 | 0.15 | nd | nd-0.79 | nd | nd | nd | 0.95 | 0.38 | 0.03–3.46 |
| BDE-85 | 0.062 | 0.01 | nd-0.41 | 0.005 | nd | nd-0.05 | nd | nd | nd-0.006 | 0.18 | nd | nd-1.60 | nd | nd | nd | nd | nd | nd |
| BDE-154 | 0.12 | 0.13 | nd-0.36 | 0.02 | 0.02 | nd-0.05 | 0.01 | 0.008 | 0.002–0.04 | 0.11 | nd | nd-0.80 | nd | nd | nd | 0.53 | 0.22 | 0.02–2.04 |
| BDE-153 | 0.2 | 0.25 | nd-0.60 | 0.03 | 0.03 | nd-0.08 | 0.03 | 0.02 | 0.009–0.10 | 0.5 | nd | nd-4.11 | 0.02 | 0.01 | nd-0.05 | 0.9 | 0.40 | 0.02–3.26 |
| BDE-138 | 0.083 | 0.008 | nd-0.35 | nd | nd | nd | 0.01 | 0.01 | nd-0.02 | 0.72 | nd | nd-5.86 | 0.003 | nd | nd-0.02 | 0.12 | nd | nd-0.73 |
| BDE-183 | 0.18 | 0.19 | nd-0.46 | 0.03 | 0.03 | nd-0.09 | 0.04 | 0.02 | 0.01–0.12 | 0.1 | 0.006 | nd-0.43 | 0.02 | 0.02 | 0.006–0.04 | 0.62 | 0.27 | 0.01–2.40 |
| BDE-190 | 0.21 | 0.20 | nd-0.57 | 0.007 | nd | nd-0.06 | 0.02 | 0.02 | 0.007–0.03 | 0.25 | nd | nd-0.63 | 0.01 | nd | nd-0.04 | 0.38 | 0.30 | nd-1.08 |
| ΣPBDEs | 2.67 | 2.53 | 1.25–5.10 | 0.3 | 0.19 | 0.007–0.90 | 0.24 | 0.24 | 0.09–0.67 | 2.87 | 0.31 | nd-18.27 | 0.12 | 0.09 | 0.06–0.27 | 7.84 | 5.30 | 0.44–23.96 |

nd: not detected.

consumption, should be evaluated.

Consequently, the present study aimed to (1) document the concentration and congener profiles of PBDEs in various tissues of hens sold in Guangzhou; (2) estimate the intake of PBDEs through hen consumption and associated PBDEs exposure risks for Guangzhou residents.

## 2. Materials and methods

### 2.1. Sample collection

In August 2016, 25 hens were randomly purchased from different markets in Guangzhou. After the hens were euthanized, blood samples were collected by medical blood vessels, centrifuged, and the supernatant transferred into brown glass bottles. Muscle, liver, fat, yolk, and ingluvies tissues were excised, washed with deionized water, and wrapped in aluminum foil. Twenty-five chicken muscle samples were collected from 25 hens. Nine samples each of blood, liver, fat, yolk, and ingluvies tissues were collected from nine hens. All samples were stored at −20 °C until analysis.

### 2.2. Sample extraction and clean-up

The method used for sample extraction and clean up was as previously reported with some modifications (Cai et al., 2011; Meng et al., 2007). 2 ml serum was combined with surrogate standard PCB-209, HCl (6 M) and isopropanol, mixed vigorously, and extracted three times with hexane/Methyl tert-butyl ether (1:1, V/V). The combined extract was concentrated to dryness and the lipid weight determined gravimetrically. The extract was then dissolved with n-hexane, and clean up performed using a gel permeation chromatography column and a complex silica-alumina column. Muscle, liver, fat, yolk, and ingluvies were freeze-dried, ground to powder, and weighed. A suitable amount of each was then subjected to soxhlet extraction with hexane/acetone (1:1, V/V) for 72 h. A similar cleanup procedure was used as for the blood samples. The eluent was concentrated to 200 µl and spiked with internal standard $^{13}$C-PCB-208 for instrumental analysis.

### 2.3. Instrumental analysis

Thirteen PBDE congeners (BDE-17, −28, −47, −66, −71, −85, −99, −100, −138, −153, −154, −183, and −190) were determined and quantified by gas chromatograph-mass spectrometer (Agilent 7890A/5975C) using negative chemical ionization (NCI) in selected ion monitoring (SIM) mode. A DB-XLB capillary column (J&W Scientific, 30 m × 0.25 mm i.d., 0.25 µm film thickness) was used to determine the PBDE congeners. Temperatures of the injection port, ion source and transfer line were 290 °C, 200 °C and 290 °C, respectively. The GC temperature gradient was 110 °C (1 min), 8 °C/min to 180 °C (1 min), 2 °C/min to 240 °C (5 min), 2 °C/min to 280 °C (15 min), and 10 °C/min to 310 °C (5 min). The following monitored ions were used: m/z 79 and 81 for target PBDEs, m/z 498 and 500 for PCB-209, m/z 475.7 and 473.7 for the internal standard $^{13}$C-PCB-208.

### 2.4. QA/QC

One procedural blank, one matrix spiked sample and one sample triplicate were run in parallel with every batch of nine samples. The average recoveries were 88 ± 13% for PBDE standards and the surrogate standard. Solvent blank and standard solution were regularly injected to control the instrumental quality. The limit of detection (LOD) of PBDE congeners was in the range of 1–5 pg.

### 2.5. Statistical analyses

All data were statistically analyzed using SPSS 16.0 software and