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PBBs, PBDEs, and PCBs in foods collected from e-waste disassembly sites and daily intake by local residents

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ABSTRACT

This study was conducted to estimate the total daily dietary intakes (TDIs) of three PHAHs subfamilies for residents living around the large e-waste disassembly sites in the Zhejiang province of China. A total of 191 food samples (including seven food groups and drinking water) were obtained from the disassembly sites and the control site in April, 2007. The levels of three PHAHs were measured by GC-MS. The estimated TDIs of PBBs (385.5 ng day^{-1}), PBDEs (195.9 ng day^{-1}), and PCBs (12,372.9 ng day^{-1}) in the disassembly sites were approximately 2–3 times higher than those in the control site, which suggested that these PHAHs from e-waste might have entered into the food chain. Rice appeared to be the food group showing the highest contribution to the individual dietary intakes of these PHAHs. The estimated TDIs were also compared with those results reported recently in the literature and their respective reference doses by WHO (or Health Canada). By and large, although the estimated TDIs for the PHAHs under study were lower than their respective reference doses, they were obviously higher than those observed in other places listed in the literature, thus suggesting that residents living around the disassembly sites have been exposed to higher levels of PHAHs than those places, and might thus be at greater health risk.

1. Introduction

Electronic waste, or otherwise known as "waste electrical and electronic equipment", or "e-waste" for short, is a pressing pollution issue driven by the rapid increase of obsolete or end-of-life electronic goods, such as computers, printers, copying machines, television sets, and mobile phones, that are left in the environment (EU, 2003). Recently e-waste has become the fastest growing category of all solid waste found in China in that huge amounts of such waste are constantly being generated from (legal or illegal) imports and domestic use (Hicks et al., 2005). A cluster of small villages in the south-eastern portion in the Zhejiang province has become a booming recycling center for e-waste, but nonetheless at the expense of having thousands of villager workers engaged in primitive recycling operations without adequate protective equipment. These primitive operations include, but are not limited to, stripping of metals in open pit acid baths, removing electronic components from circuit boards by heating over a grill, and recovering metals by burning cables in (or near) the cropland (BAN, 2002; Wong et al., 2007). Yet as a result of these operations and through leakage, evaporation, runoff, and leaching, many toxic chemicals, such as polybrominated diphenyl ethers (PBDEs) and polychlorinated biphenyls (PCBs), have been reported to release into the local environmental matrices such as air (Deng et al., 2007), sediment (Wang et al., 2005; Luo et al., 2007), and soil (Liu et al., 2008; Zhao et al., 2008). These pollutants can be bioaccumulated in

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Fig. 1 – Sampling sites (•) in Zhejiang Province, China.

the aquatic and the terrestrial food chains and biomagnified in humans via food due to their lipophilicity (Zhao et al., 2007). However, there is still no report on food contamination by polyhalogenated aromatic hydrocarbons (PHAHs) and dietary intake estimation near e-waste disassembly sites in China.

PHAHs represent a large family of highly lipophilic and environmentally persistent substances, of which polybrominated biphenyls (PBBs) and PBDEs are two subfamilies that were of great concern in the present study. These two subfamilies have been used extensively as flame retardants for many years (BSEF, 2001). Recent studies by Zhao et al. (2008) suggested that these e-wastes are important sources for the emission of PBBs and PBDEs into local environments. PCBs were the third and last subfamily considered in the present study. Recent studies by Zhao et al. (2006, 2007, 2008) suggested that obsolete transformers and electrical waste are important sources for the emission of PCBs into local environments. In addition to being highly lipophilic and persistent in the environment, all three PHAHs subfamilies are notably toxic and bioaccumulative (Hardy, 2000; McDonald, 2002). Animal studies (WHO, 1994a,b) showed that the PHAHs in these three subfamilies not only were they capable of disrupting endocrine functions but could also induce neurodevelopmental, hepatic, reproductive, and other adverse health effects. Foods generally represent the largest source for chemicals found in our bodies; the World Health Organization (2005) believes that most chronic health conditions can be attributed to past and current exposure to chemicals in the foods humans eat. Accordingly, an exploratory effort was made in the present study to monitor the levels of 62 PHAHs in food samples collected at a recycling cluster (center) and a control site. The sampling sites were all located on the southeast side of the Zhejiang province. The PHAHs under consideration were 23 PBB congeners, 12 PBDE congeners, and 27 PCB congeners, as listed later in the result tables.

The recycling center consisted of four e-waste disassembly sites which collectively represented large sections of the towns (villages) Tongshan, Panlang, Xiazheng, and Xinqiu. These towns or villages are located near the city of Wenling, which is on the southeast side of Zhejiang (Fig. 1). The town Yandang, located in a remote mountainous area 30 km SW of the recycling cluster, was used as a control site. In the villages under study, residents commonly provide their own foods by family labor. For example, rice and vegetables were planted in their own croplands; pigs and chicken were raised in their farmyards; and fish were cultured in their ponds. The foods that the local residents had in excess, which were usually in small portions, were sold to their local grocery stores. Therefore, the foods available in the local grocery stores could and should serve to represent the food contamination situation in each of the towns under study.

The present study assessed the dietary exposure of local residents to the 62 PHAHs that were deemed likely present in e-waste. In particular, this exploration represented the first of its kind in reporting extensively the recent levels of PBBs, PBDEs, and PCBs in the food groups from the disassembly and control sites in China. Information obtained from this type of exploration may also be very useful for subsequent evaluation of the health risks at issue.

2. Materials and methods

2.1. Sample collection and storage

In April 2007, a total of 175 food samples were obtained in local grocery stores (or residents' family) from these e-waste disassembly sites and from the control site, and grouped into the following seven types (detailed description listed in Table 1): vegetables (Chinese mustard, greengrocery, and green beans), pork and chicken (~0.2 kg), rice, fish and shellfish (about 0.2 kg for each carp, each with 2 subsamples); pulses (each with 2 subsamples); and eggs (each with 6 subsamples). The seven food groups represent the most widely used in Zhejiang Province. 8 water samples were also obtained from the local wells for drinking (each with 2 subsamples of ~2 L). Each food sample, after being placed into a separate chemically-clean polyethylene bottle, was labeled with a unique code and the proper sampling date. All samples were immediately transported to the analytical laboratory in ice boxes rapidly and stored in the dark at 4 °C until analysis.

2.2. Materials and chemicals

The following standards were obtained from the Cambridge Isotope Laboratory (USA): 12 native PBDE congeners; 7 $^{13}C_{12}$-labeled PBDEs (PBDE15, 28, 47, 99, 153, 154, and 183); 23 PBB congeners; 27 PCB congeners; and surrogate standards pentachloro- nitrobenzene (PCNB), 2,4,5,6-tetrachloro-m-xylene (TMX), and PCB209. All solvents used (acetone, hexane, methanol, and methylene chloride) were of pesticide grade (Promochem, Germany). Solid-phase extraction (SPE) cartridges packed with C_{18} sorbent (500 mg) were obtained from Waters Corporation (Milford, MA, USA). Silica gel (100–200 mesh) was also purchased from Promochem (Germany). Aluminum foil was rinsed with acetone and dried at ambient temperature prior to use. Sodium sulfate (granular, anhydrous) was pre-cleaned with methylene chloride and purified by heating at 450 °C for 8 h in a shallow metallic enamel tray. Cellulose extraction thimbles of 33 mm i.d. and 94 mm in length were from Schleicher & Schuell (Germany); these thimbles were pre-cleaned by Soxhlet extraction with *n*-hexane:acetone (3:1, v/v) for 4 h before use. Glassware was soaked, cleaned with chromic solution, rinsed thoroughly with distilled water and acetone, and finally heated in a baking oven (Heraeus, Germany) at temperatures programmed from 40 °C to 420 °C at a rate of 15 °C min^{-1} for 16 h.

Table 1 – Samples collected from the control site and the disassembly sites of Zhejiang, China

Samples	The control site (*n*)	The disassembly sites (*n*)	Quantity in each sample
Drinking water	3	5	2
Vegetables	3	19	1
Pulses	3	5	2
Rice	3	8	1
Hen eggs	3	12	6
Fish	3	8	2
Pork	3	5	1
Chicken	3	3	1
Sum[a]		191	

[a]: Sum = $\Sigma(n_{\text{food in the control site}} + n_{\text{food in the disassembly site}}) \times$ Quantity in each sample.

2.3. Sample preparation and clean-up

The PHAH residues in dinking water samples were extracted according to the modified method-3535a (US EPA, 2007). Prior to extraction, the SPE cartridges were pre-eluted with methylene chloride, activated with methanol and water, and the cartridges were not allowed to dry. Water samples were first filtered through glass fiber filters (0.45 μm pore size, Millipore, Bedford, MA, USA); TMX, PCNB, and PCB209 were added to each water sample as surrogate congener standards. After extraction, the SPE cartridge was separately eluted with three portions of 5 ml each, *n*-hexane, *n*-hexane:methylene chloride (9:1, v/v) and *n*-hexane:methylene chloride (1:1, v/v), the eluates were dried with anhydrous sodium sulfate column, concentrated to dryness under gentle nitrogen and redissolved in 200 μL hexane.

Vegetables, rice, pulses, pork, chicken, and fish muscle were first homogenated individually, the eggs were opened and their contents were individually poured in chemically cleaned glass bottles and freeze-dried. The dried samples were directly ground into powder in mortars. About 2–5 g of these samples was introduced into pre-cleaned thimbles and Soxhlet extracted for 24 h using 180 mL *n*-hexane/acetone (3:1) solution. For this preparation process, TMX, PCNB, and PCB209 were added to each sample as surrogate congener standards. The extract from each sample was then concentrated to about 1 mL by rotary evaporation (550 mbar, 60 °C). The concentrated extracts were further cleaned individually by a multilayer silica gel column containing: 2 g of anhydrous sodium sulfate; 8 g of silver nitrate ($AgNO_3$) silica (10%, $AgNO_3$ w/w); 2 g of deactivated silica (3.3% organic-free reagent water w/w); 15 g of acidic silica (44% conc. sulphuric acid w/w); 1 g of deactivated silica (3.3% organic-free reagent water w/w); and 2 g of anhydrous sodium sulfate. The silica gel column was pre-eluted with 80 mL of hexane prior to adding to the extract. The first fraction eluted with *n*-hexane (100 mL) was used to concentrate the PCB congeners, with the second fraction (eluted with 10% methylene chloride in 80 ml *n*-hexane) intended for collection of the PBB and PBDE congeners (US EPA, 1996; Liu et al., 2008). The eluants were concentrated separately to about 1 mL, again by rotary evaporation. The solvent of each sample was evaporated to dryness by gentle nitrogen stream at 25 °C and redissolved in 200 μL hexane.

2.4. Chemical analysis

The chemical analysis was performed using an Agilent 5975 GC-MS system equipped with a capillary DB-5MS column (5% phenyl/95% methyl silicone, 30 m, 0.25 mm i.d., 0.25 μm film thickness, from J&W Scientific, Folsom, California, USA). The column oven temperature was programmed from 90 °C (initial time, 1 min) to 250 °C at a rate of 4 °C min^{-1}, then from 250 °C to

Table 2 – Total dietary intakes (TDIs) of *PBBs* (in ng day^{-1}) for residents living in the control site and the disassembly site of Zhejiang, China [a]

Pollutants	The control site									The disassembly site								
	Water	Vegetables	Pulses	Rice	Hen eggs	Fish	Pork	Chicken	TDIs	Water	Vegetables	Pulses	Rice	Hen eggs	Fish	Pork	Chicken	TDIs
Intake[b]	2000	225	5	310	13	42	43	10	–	2000	225	5	310	13	42	43	10	–
PBB1	0.2	N.A.	0.1	N.A.	N.A.	N.A.	N.A.	N.A.	0.4	0.4	N.A.	0.3	N.A.	N.A.	N.A.	N.A.	N.A.	0.7
PBB2	N.A.	1.6	0.3	14.9	0.8	5.5	2.3	0.5	25.8	N.A.	2.7	0.5	20.8	0.6	6.8	2.7	0.4	34.5
PBB3	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.
PBB10	0.8	N.A.	0.1	11.0	0.4	N.A.	1.6	0.2	14.2	0.8	1.7	0.1	11.0	0.5	3.0	1.6	0.3	19.1
PBB4	0.8	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	0.8	0.8	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	0.8
PBB9	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.
PBB7	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.
PBB15	0.3	N.A.	0.2	19.5	N.A.	2.9	2.7	0.6	26.2	1.5	N.A.	0.2	19.2	0.9	9.0	1.8	0.6	33.3
PBB30	0.4	1.4	0.2	N.A.	N.A.	N.A.	1.5	0.4	3.9	1.3	2.2	0.2	11.4	0.7	7.0	2.9	0.4	26.1
PBB18	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.
PBB29	N.A.	3.5	0.1	11.5	0.5	N.A.	1.8	0.7	18.1	1.5	N.A.	0.2	20.8	0.9	5.3	2.7	0.7	32.1
PBB26	N.A.	3.0	N.A.	N.A.	0.5	N.A.	N.A.	0.3	3.8	N.A.	N.A.	0.1	10.9	0.8	2.9	1.8	0.3	16.8
PBB31	N.A.	N.A.	0.1	N.A.	0.5	N.A.	1.6	0.6	2.8	N.A.	N.A.	0.2	14.6	0.9	4.5	2.9	0.6	23.7
PBB53	N.A.	N.A.	0.1	N.A.	N.A.	N.A.	N.A.	N.A.	0.1	N.A.	N.A.	0.2	N.A.	N.A.	N.A.	N.A.	N.A.	0.2
PBB38	N.A.	2.9	0.1	N.A.	N.A.	N.A.	1.7	0.4	5.1	0.8	N.A.	0.1	15.6	1.0	7.0	3.1	0.9	28.5
PBB52	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.
PBB49	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.
PBB103	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	8.9	N.A.	N.A.	N.A.	N.A.	8.9
PBB80	N.A.	3.3	0.1	11.2	N.A.	3.3	N.A.	0.5	18.4	N.A.	N.A.	0.2	25.0	1.3	13.6	3.8	1.0	44.9
PBB101	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.
PBB155	N.A.	3.4	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	3.4	N.A.	N.A.	N.A.	N.A.	0.1	N.A.	N.A.	N.A.	0.1
PBB153	N.A.	N.A.	N.A.	24.7	0.3	N.A.	3.4	1.0	29.4	0.4	N.A.	0.2	13.5	0.8	5.2	3.2	0.9	24.2
PBB209	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.
ΣPBBs	4.3	21.5	1.5	119.9	4.8	20.3	19.2	5.8	197.3	9.4	21.7	3.5	227.0	8.9	79.9	28.4	6.9	385.5
Percent[c]	2.2	10.9	0.7	60.8	2.4	10.3	9.7	2.9	100.0	2.4	5.6	0.9	58.9	2.3	20.7	7.4	1.8	100.0

[a]: Dietary intake of *PBB congener* = C_{food} *X Intake of each food type*; Water: Drinking water; N.A.: not available, which represent the congener was not detected in the experiment process, or statistical analyses were not performed due to lower than 50% of the samples above the LOD for the congener; [b]: Based on the statistical results summarized by national bureau of statistics of China (in g day^{-1}, http://www.stats.gov.cn/tjsj/ndsj/2006/indexch.htm); [c]: The percent of PBBs intake for every food type accounts for the estimated TDIs.

Table 3 – Total dietary intakes (TDIs) of PBDEs (in ng day^{-1}) for residents living in the control site and the disassembly site of Zhejiang, China [a]

Pollutants	The control site									The disassembly site							
	Water	Vegetables	Pulses	Rice	Hen eggs	Fish	Pork	Chicken	TDIs	Water	Vegetables	Pulses	Rice	Hen eggs	Fish	Pork	Chicken	TDIs
Intake[b]	2000	225	5	310	13	42	43	10	–	2000	225	5	310	13	42	43	10	–
PBDE3	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.
PBDE15	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.
PBDE17	N.A.	N.A.	N.A.	N.A.	N.A.	3.9	N.A.	N.A.	3.9	N.A.	N.A.	0.1	N.A.	N.A.	N.A.	1.6	0.4	2.1
PBDE28	1.8	3.3	0.2	N.A.	0.6	11.0	2.8	0.8	20.4	1.8	3.7	0.1	14.5	0.8	12.0	3.7	0.8	37.3
PBDE47	N.A.	3.5	0.2	11.7	1.2	13.3	3.1	0.9	33.9	2.1	4.3	0.3	17.9	1.1	17.2	3.8	1.0	47.7
PBDE66	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	0.4	0.4
PBDE100	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	1.7	N.A.	1.7	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	2.5	N.A.	2.5
PBDE99	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.
PBDE154	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	0.9	1.0	1.9	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	0.5	0.5
PBDE153	N.A.	1.2	N.A.	N.A.	N.A.	0.7	N.A.	N.A.	2.0	N.A.	5.6	N.A.	N.A.	0.6	1.8	N.A.	N.A.	8.1
PBDE183	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	21.0	1.0	N.A.	N.A.	0.5	22.4
PBDE209	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	8.7	7.8	16.5
ΣPBDEs	2.3	9.6	0.6	24.0	2.4	35.9	9.8	3.5	88.1	4.3	15.0	0.8	90.9	4.8	43.3	23.2	13.0	195.9
Percent[c]	2.6	10.9	0.7	27.2	2.7	40.8	11.2	4.0	100.0	2.2	7.7	0.4	46.4	2.4	22.1	11.8	7.0	100.0

[a]: Dietary intake of *PBDE congener* = C_{food} *X Intake of each food type*; Water: Drinking water; N.A.: not available, which represent the congener was not detected in the experiment process, or statistical analyses were not performed due to lower than 50% of the samples above the LOD for the congener; [b]: Based on the statistical results summarized by national bureau of statistics of China (in g day^{-1}, http://www.stats.gov.cn/tjsj/ndsj/2006/indexch.htm); [c]: The percent of PBDEs intake for every food type accounts for the estimated TDIs.

300 °C at a rate of 25 °C min^{-1}, and held for 5 min. The GC injector temperature was maintained at 260 °C, with the temperatures of the MS ion source and of the transfer line being kept at 230 °C and 300 °C, respectively. The carrier gas was helium at a constant flow rate of 1.5 mL min^{-1}. The mass spectrometer was operated in the electron impact (EI) ionization mode with an electron energy of 70 eV. Samples (1 μl) were injected in the splitless mode with a solvent delay set at 4 min. The molecular ions ($[M]^+$ or $[M+2]^+$) and the fragment ions resulting from the loss of X_2 (i.e., $[M\text{-}X_2+2]^+$ or $[M\text{-}X_2+4]^+$, where X = chlorine or bromine) were selected as the precursor ions for mass spectrometric analysis (Luo et al., 2007). Quantitative analyses of PBB209 and PBDE209 were performed on the Agilent 5975 GC-MS equipped with a DB-5MS (5% phenyl/95% methyl silicone, 15 m, 0.25 mm i.d., 0.1 μm film thickness, from J&W Scientific, Folsom, California, USA), at temperatures programmed from 90 °C (initial time, 1 min) to 250 °C at a rate of 10 °C min^{-1}, then from 250 °C to 300 °C at 15 °C min^{-1}, and finally held for 8 min. Mass spectrometer condition was performed by EI (70 eV) and selected ion monitoring of high abundance (m/z 943 and m/z 799 for PBB209 and PBDE209, respectively).

2.5. *Quality assurance/quality control*

For every batch of 10 samples, a solvent blank and a procedural blank were added to ensure that the samples and the analysis process were free of contamination. The detection limits (LOD) of the targeted compounds were defined as 3 times the signal to noise (S/N) ratio, ranged from 0.08 to 0.24 ng g^{-1} dw for PBB congeners, from 0.08 to 0.32 ng g^{-1} dw for PBDE congeners, from 0.02 to 0.12 ng g^{-1} dw for PCB congeners, and from 0.80 to 1 ng g^{-1} dw for PBB209 and PBDE209. Spike recoveries for $^{13}C_{12}$-labeled PBDEs (at 10 ng) ranged from 75.2 to 96.5%; and those for TMX, PCNB, and PCB209 ranged from 70.4 to 92.5%, 81.6 to 107.4%, and 90.8 to 112.6%, respectively. Triplicate analysis of six diluted standard solutions (1.0, 5.0, 10.0, 25.0, 50.0, and 100.0 ng mL^{-1}) was performed for each selected standard mixture. Multi-level calibration curves were constructed for the quantification; and good to excellent linearity (r^2 > 0.99) was achieved.

2.6. *Estimation of total daily dietary intake*

The average daily dietary intake quantity for each adult Zhejiang resident was 225 g of vegetables, 5 g of pulses, 310 g of rice, 13 g of egg, 43 g of pork, 42 g of fish, and 10 g of chicken, respectively (http://www.stats.gov.cn/tjsj/ndsj/2006/indexch.htm), and 2 L of drinking water (Chinese Nutrition Society, 2000). The total daily dietary intakes (TDIs) of three PHAHs subfamilies for these residents were estimated according to the following formula:

$$TDI = \sum_{i=1}^{8} Ci \times DDIi$$

where C_i (ng g^{-1} ww) is the concentration of PHAHs in the food group; DDI_i is the daily dietary intake of each the seven food groups and drinking water for the adult residents.

Table 4 – Total dietary intakes (TDIs) of PCBs (in ng day^{-1}) for residents living in the control site and the disassembly site of Zhejiang, China [a]

Pollutants	The control site									The disassembly site								
	Water	Vegetables	Pulses	Rice	Hen eggs	Fish	Pork	Chicken	TDIs	Water	Vegetables	Pulses	Rice	Hen eggs	Fish	Pork	Chicken	TDIs
Intake[b]	2000	225	5	310	13	42	43	10	–	2000	225	5	310	13	42	43	10	–
PCB8	0.3	10.8	0.6	33.8	19.5	55.3	5.0	1.4	126.8	0.3	31.2	0.7	439.5	20.2	24.8	7.3	1.6	525.6
PCB18	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.
PCB28	0.5	16.0	1.3	238.9	30.1	94.1	10.2	3.2	394.4	0.5	42.1	1.5	N.A.	46.8	175.3	11.3	11.9	289.5
PCB52	0.4	11.1	0.5	167.7	17.8	63.4	6.5	1.6	269.1	0.2	26.2	0.7	438.1	17.8	173.3	7.7	3.4	667.3
PCB44	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.
PCB66	0.6	18.7	0.9	190.0	23.6	77.9	10.1	2.6	324.4	0.6	28.8	1.1	627.9	30.5	254.9	12.3	7.5	963.6
PCB101	0.5	N.A.	0.6	124.4	15.9	90.4	10.2	2.1	244.1	0.5	25.8	0.6	570.8	25.6	230.2	10.7	6.4	870.5
PCB153	0.5	15.6	0.9	182.4	21.9	94.1	12.1	2.6	330.1	0.7	17.9	1.1	563.8	33.4	157.2	13.4	4.5	792.0
PCB138	0.4	14.2	1.1	187.5	24.8	156.8	17.4	2.7	405.0	0.4	35.2	1.7	799.8	50.4	177.8	14.9	8.5	1088.8
PCB187	N.A.	N.A.	0.3	47.4	4.9	41.3	10.2	1.8	105.8	N.A.	N.A.	0.8	521.5	25.6	100.9	12.5	N.A.	661.2
PCB128	N.A.	22.1	0.9	200.6	20.3	80.6	10.7	2.8	338.0	N.A.	21.5	1.0	639.1	22.8	146.2	14.1	3.9	848.5
PCB180	N.A.	N.A.	0.4	206.8	28.3	143.8	12.0	2.9	394.3	N.A.	21.8	1.4	804.8	42.3	100.7	12.7	6.0	989.7
PCB170	0.8	6.8	1.3	56.7	21.1	120.2	16.1	3.0	226.1	0.8	N.A.	1.8	675.3	37.6	207.7	16.0	5.5	944.7
PCB195	N.A.	14.1	1.0	211.5	22.8	87.5	8.1	3.0	347.8	0.5	N.A.	0.8	592.6	24.4	131.7	9.0	3.1	762.0
PCB206	0.5	16.0	N.A.	232.5	25.3	46.6	13.5	3.2	337.6	0.8	17.3	N.A.	636.1	26.0	103.6	12.6	3.2	799.5
PCB77	N.A.	5.9	0.5	42.0	1.9	17.4	4.6	1.2	73.5	N.A.	7.2	0.6	53.7	1.7	21.0	5.5	1.7	91.4
PCB81	N.A.	5.9	0.4	41.7	1.8	16.3	4.4	1.2	71.7	N.A.	7.6	0.3	49.3	1.7	18.8	5.5	1.2	84.3
PCB105	N.A.	5.9	0.3	29.0	0.7	14.7	4.0	0.9	55.5	0.1	9.3	0.3	32.0	1.8	24.7	5.8	1.3	75.3
PCB114	0.1	5.7	0.3	29.2	0.6	14.4	3.9	0.9	55.3	0.1	5.4	0.3	31.8	1.5	14.3	4.5	2.4	60.4
PCB118	N.A.	N.A.	0.3	0.0	0.6	11.5	3.1	0.9	16.3	N.A.	N.A.	0.3	N.A.	1.1	12.0	4.8	1.3	19.5
PCB123	N.A.	N.A.	0.3	30.3	0.6	13.4	3.5	0.8	48.9	N.A.	N.A.	0.3	32.7	1.7	13.5	5.4	0.9	54.5
PCB126	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	0.2	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	0.2
PCB156	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.
PCB157	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.
PCB167	N.A.	N.A.	0.2	N.A.	1.2	11.7	1.6	N.A.	14.7	N.A.	N.A.	0.2	20.7	0.9	N.A.	N.A.	N.A.	21.8
PCB169	N.A.	N.A.	N.A.	N.A.	0.3	N.A.	0.6	0.2	1.1	N.A.	N.A.	N.A.	N.A.	0.4	N.A.	1.0	0.3	1.7
PCB189	0.4	6.5	0.7	62.5	1.8	19.9	4.6	1.1	97.4	0.3	N.A.	0.8	64.9	1.8	18.2	5.8	1.2	93.0
ΣPCBs	5.9	226.2	14.2	2564.8	302.4	1345.0	175.2	39.9	4673.7	6.5	477.8	17.9	8599.9	449.8	2526.3	202.3	92.3	12372.9
ΣTEQs[c]	0.3	5.9	0.6	37.7	4.0	16.7	8.5	3.2	76.9	9.5	17.6	0.5	100.0	5.2	45.8	12.8	5.2	196.6
Percent[d]	0.1	4.8	0.3	54.9	6.5	28.8	3.7	0.9	100.0	0.1	3.9	0.1	69.5	3.6	20.4	1.6	0.7	100.0

[a]: Dietary intake of *PCB congener* = C_{food} *X Intake of each food type*; Water: Drinking water; N.A.: not available, which represent the congener was not detected in the experiment process, or statistical analyses were not performed due to lower than 50% of the samples above the LOD for the congener; [b]: Based on the statistical results summarized by national bureau of statistics of China (in g day^{-1}, http://www.stats.gov.cn/tjsj/ndsj/2006/indexch.htm); [c]: TEQs = toxic equivalence quotients (in pg day^{-1}), which each were calculated using the World Health Organization method and toxic equivalence factors (Van den Berg et al., 2006) in an effort to weight the toxicity as well as the potency of dioxin (2,3,7,8-TCDD)-like PCB compounds (i.e., those last 12 PCBs listed in this table) in relation to that of TCDD; [d]: The percent of PCBs intake of every food type accounts for the estimated TDIs.

2.7. Data analysis

A value of half LOD was given to the samples in which the contents of PBBs, PBDEs or PCBs were not detectable. Descriptive statistics (mean, etc.) were computed to characterize the concentrations of PBBs, PBDEs, and PCBs in the samples. All statistical analyses were performed for congeners for which more than 50% of the samples were above the LOD, using the Statistical Package for the Social Sciences (SPSS for Windows ver. 11.5) where applicable. The (statistical) term *mean* used throughout this paper referred to *geometric* mean. Nonparametric methods (Mann–Whitney U) was used to determine differences in PHAHs levels between disassembly sites and the control site, all statistical significance was set at Alpha=0.05.

3. Results

3.1. PBBs measured in food samples and daily intake by local residents

The intakes of PBBs through drinking water, vegetables, rice, pulses, hen eggs, pork, chicken, and fish muscle consumption are summarized in Table 2. These data showed that among drinking water and the seven groups food samples, the highest intake of PBBs (119.9 ng day^{-1}) found in the control site apparently were mainly through rice consumption, which accounted for approximately 60.8% of the estimated TDI of PBBs, the intake of PBBs through vegetables, hen eggs, and fish muscle consumption also separately accounted for 11.0%, 10.3% and 9.7% of the total PBBs intake observed. PBB153 (29.4 ng day^{-1}), PBB15 (26.2 ng day^{-1}), PBB2 (25.8 ng day^{-1}), PBB80 (18.4 ng day^{-1}), and PBB29 (18.1 ng day^{-1}) were found as the most predominant contributors for dietary intake of PBBs.

The PBBs intakes (385.5 ng day^{-1}) for the local residents living around the disassembly sites were significantly ($P<0.01$) greater than those (197.3 ng day^{-1}) in the control site. The highest intake of PBBs (227.0 ng day^{-1}) were mainly through rice consumption, which accounted for approximately 58.9% of the TDI of PBBs, the second highest intake of PBBs (79.9 ng day^{-1}) through fish muscle consumption also accounted for 20.7% of the total PBBs intake observed; PBB80 (44.9 ng day^{-1}), PBB2 (34.5 ng day^{-1}), PBB15 (33.3 ng day^{-1}), PBB29 (32.1 ng day^{-1}), and PBB38 (28.5 ng day^{-1}) were found as the most predominant contributors for the estimated TDI of PBBs. PBB209 was not detected in these sampled foods.

3.2. PBDEs measured in food samples and daily intake by local residents

The intakes of PBDEs through drinking water and food consumption are summarized in Table 3, which shows that the intake through fish muscle consumption had the highest PBDEs intake (36.8 ng day^{-1}) among the seven groups of food samples and drinking water collected from the control site. The data in this table also showed that PBDE47 (33.9 ng day^{-1}) was the most predominant congeners for the estimated TDI of PBDEs. For food samples from the disassembly sites, the intake of PBDEs (195.9 ng day^{-1}) was approximately 2 times higher than those (88.1 ng day^{-1}) from the control site. The intakes through rice and fish muscle consumption had the highest PBDEs levels (90.9 and 43.3 ng day^{-1}); PBDE47 (47.7 ng day^{-1}) was the most predominant congeners. PBDE209 were also detected in more than 60% of the pork and chicken samples, which accounted for 8.4% of the total PBDEs intake.

3.3. PCBs measured in food samples and daily intake by local residents

As summarized in Table 4 (and Tables 2 and 3), among the three subfamilies of PHAHs, PCBs had the highest intake level through drinking water and selected food consumption in the control site (4673.7 ng day^{-1}) and the e-waste disassembly sites (12,372.9 ng day^{-1}). PCB138 was the most predominant contributor of the estimated TDIs of PCBs in both the control site and the disassembly sites, which separately reached 405.0 ng day^{-1} and 1088.8 ng day^{-1}. The highest intake of PCBs were both mainly through rice consumption in the control site and disassembly sites, which separately accounted for 54.9% and 69.5% of the estimated TDIs of PCBs, the second highest intakes of PCBs were both through fish muscle consumption, which were 1345.0 and 2526.3 ng day^{-1}, respectively. The intake of ΣTEQ_{PCBs} were separately 76.9 and 196.6 pg day^{-1} in the control site and the disassembly sites, their intake were also both mainly through rice and fish muscle consumption. As common practice, here the level ΣTEQ_{PCBs} referred to the sum of the toxic equivalents (or toxic equivalence quantities), which each were calculated using the World Health Organization method and toxic equivalence factors (Van den Berg et al., 2006) in an effort to weight the toxicity as well as the potency of dioxin (2,3,7,8-TCDD)-like PCB compounds (i.e., those last 12 PCBs listed in Table 4) in relation to that of TCDD.

4. Discussion

The environmental matrices (such as air, sediment, and soil) in the disassembly sites have been serious polluted by PHAHs sourced from e-waste (Wang et al., 2005; Deng et al., 2007; Luo et al., 2007; Liu et al., 2008; Zhao et al., 2008), these pollutants could enter into the food chain through different pathways from these polluted environmental matrices. For examples, the predominant pathways for uptake of these hydrophobic compounds by plants (such rice and vegetables) are kinetically limited uptake and dry particulate deposition from the atmosphere (McLachlan, 1996, 1999; Chu et al., 1999). PHAHs show a strong tendency to partition from the gas phase onto atmospheric particles due to their high octanol-air partition coefficient (McLachlan, 1999), which results in an increase in the importance of dry particle-bound deposition. In fact, one of the biogeochemical processes responsible for chemical bioaccumulation is solvent switching, in which a chemical takes the course toward thermodynamic equilibrium by concentrating itself in one medium over another (MacDonald, 2002; Blais, 2005). According to Blais (2005), solvent switching occurs when a hydrophobic chemical (e.g., PCB) tends to accumulate in a fish's gill all because the chemical's lipid solubility is much greater than its aqueous solubility.

Table 5 – Total dietary intakes (TDIs) of PBBs, PBDEs, and PCBs (in ng day^{-1}) in various localities in China and in other countries [a]

Countries (or districts)	Sampling year	Characteristics of the study	PBBs	PBDEs	PCBs	TEQPCBs	References
Finland	1997	Total diet baskets	–	43–45[b]	1200[c]	60[d]	Kiviranta et al. (2004)
Italy	1998	Duplicate diet	–	–	3720[e]	–	Zuccato et al. (1999)
Dutch	1998–1999	National food consumption survey	–	–	336[f]	72[g]	Baars et al. (2004)
Sweden	1999	Market baskets	–	51[b]	615[h]	41.4[i]	Darnerud et al. (2006)
European Commission	–	Total diet study	–	–	–	48–90[g]	SCF (2001)
UK	1999–2000	Duplicate diet	–	90.5[j]	–	–	Harrad et al. (2004)
Spain (Catalonia)	2000	Total diet study	–	82–97[k]	–	–	Bocio et al. (2003)
Canada (Vancouver)	2002	Total diet study	–	30.4	160	–	Health Canada (2002)
Japan	2002–2003	Market baskets	–	114[l]	–	–	Ashizuka et al. (2004)
USA	2003–2004	Market baskets	–	54[m]	–	–	Schecter et al. (2006)
Dutch	2003–2004	National food consumption survey	–	102[n]	–	–	De Winter-Sorkina et al. (2006)
Belgium	2005	General Belgian population	–	23–48[o]	–	–	Voorspoels et al. (2007)
USA (Michigan)	–	Subpopulation in Michigan	360–36,000	–	–	–	WHO (1994a)
USA	–	General USA population	120	–	–	–	WHO (1994a)
WHO	–	NOAEL	9×10^{6} [p]	–	–	–	WHO (1994a)
Canada	–	pTDI	–	–	6×10^{4} [q]	–	Health Canada (1996)
Sweden	–	LOAEL	–	6×10^{7} [r]	–	–	Darnerud et al. (2001)
The control site	2007	Total intake by adults	197.3	88.1	4673.7	76.9	Present study
The disassembly site	2007	Total intake by adults	385.5	195.9	12,372.9	196.6	

[a]:LOAEL: lowest-observed-adverse-effect level; NOAEL: no observed-adverse-effect level produce chronic toxic effects and cancer by in animals; [b]: PBDE 47, 99, 100, 153, and 154; [c]: PCB18, 28, 33, 49, 52, 60, 66, 74, 77, 99, 101, 105, 110, 114, 118, 122, 123, 126, 128, 138, 141, 153, 156, 157, 167, 169, 170, 180, 183, 187, 189, 194, 206, and 209; [d]: PCB77, 105, 114, 118, 123, 126, 156, 157, 167, 169, and 189; [e]: PCB28, 52, 77, 81, 101, 105, 114, 118, 123, 126, 138, 153, 156, 157, 167, 169, 180, and 189; [f]: PCB28, 52, 101, 118, 138, 153, and 180; [g]: PCB77, 81, 105, 114, 118, 126, 156, 157, 167, 169; 77, 105, 114, 118, 123, 126, 156, 157, 167, 169, and 189; [h]: PCB28, 52, 77, 101, 105, 118, 126, 138, 153, 169, and 180; [i]: PCB77, 126, and 169; [j]: PBDE47, 99, 100, 153, and 154; [k]: sum of tetra- to octaBDEs; [l]: PBDE 47, 49, 66, 99, 100, 153, 154, and 183; [m]: PBDE17, 28, 47, 66, 77, 85, 99, 100, 138, 153, 154, 183, and 209; [n]: PBDE28, 47, 66, 85, 99, 100, 138, 153, 154, and 183; [o]: PBDE28, 47, 99, 100, 153, 154, and 183. [p]: 9×10^{6} was obtained according to 0.15 mg/kg/d (NOAEL for PBBs, WHO, 1994a) × 60 kg (60 kg is the average BW assumed for adult Chinese) × 10^{6}; [q]: 6×10^{4} was obtained according to 1 μg/kg bw/d (pTDI for PCBs, Health Canada, 1996) × 60 kg × 10^{3}; [r]: 6×10^{7} was obtained according to 1 mg/kg/d (LOAEL for PBDEs, WHO, 1994a,b) × 60 kg × 10^{6}.

Therefore, fish can bioaccumulate these pollutants from a combination of surface sediments and the water column (Hale et al., 2001). The foraging domestic animals and fowls could accumulate PHAHs in body from environment by the pathways: ingestion of soil, ingestion of organisms (such as plants, annelids etc.), inhalation of dust, and skin contact, and so on (Schuler et al., 1997). Overall, the intakes of PHAHs in the three subfamilies (i.e., the PBBs, PBDEs, and PCBs) were all considerably higher ($P<0.05$) through drinking water and food consumption in the disassembly sites than from the control site Yandang. These facts all collectively supported the notion that the PHAHs under study have entered into the aquatic and the terrestrial food chains through bioaccumulation.

In the study sites, the foods of vegetable origin (rice and vegetables) account for 83% of the total seven food groups intake, and those of animal origin only account for 17% of the total intake, which mainly include fish (6.5%), fowl (1.5%), pork (6.6%), and egg (2.0%); and other foods of animal origin almost can't be found in these local grocery stores. Bocio et al. (2003) reported that intake of animal origin foods account for 46.7% (including fish (6.4%), meat (12.8%), egg (2.4%), dairy product (7.3%), milk (15.0%), and fat (2.8%)) in Spanish (Catalonia) dietary intake. The fact shows that the village residents' food habits and traditions in Zhejiang Province (China) are different from those in Spain (or other countries), foods of vegetable origin are the primary foods. By and large, the highest intake of the PHAHs under study were all mainly through rice consumption in the control site and the disassembly site (excluding PBDEs intake in the control site) (Tables 2 and 4), which should be due to the highest quantity of rice intake (310 g day^{-1}) in comparison with other foods listed in Table 1 and high PHAHs level observed in these rice samples. Darnerud et al. (2006) also stated that food intake mainly depending on national or regional food habits and traditions, the actual intake of PHAHs from different food groups, may vary considerably.

4.1. PBBs

PBBs were once manufactured for commercial use typically consisted of *hexa*-, *octa*-, *nona*-, and *deca*bromobiphenyls (WHO, 1994a,b), which could be released from electrical and electronic products with relative ease since they were only *physically* mixed into the products and not chemically bound to them. Based on a use life-expectancy of 5–10 years for most electrical and electronic products, it is anticipated that many of the PBB-containing products now have already been discarded (US ATSDR, 2004). Large quantities of e-waste are reported (BAN, 2002) to have been shipped to developing countries, including China, to be salvaged for usable parts. High level of PBBs was detected in the e-waste residue samples (cable coating, stuffing powder, and chipped circuit

boards), surface soil have been heavily polluted with PBBs (Zhao et al., 2008). Though PBBs in the atmosphere of the disassembly sites have not been proven, PBBs may be released into the atmosphere as vapour or dust from these PBB-containing e-waste residues. Stratton and Whitlock (1979) found indirect evidence of airborne discharges of PBBs near two out of three chosen industrial sites in north-eastern New Jersey and Staten Island, New York, where these materials had been manufactured or used in product formulations. The plants (such rice and vegetables) can thus accumulate PBBs by dry gaseous deposition from the atmosphere. As above-mentioned, PBBs can be bioaccumulated into the food chains through complex biogeochemical processes, these facts tend to support the higher level of PBBs observed in the food samples collected from the disassembly sites. As stated earlier, the low-brominated PBBs (such as PPB2, PBB15, PBB29, PBB38 and PBB80) were found as the most predominant contributors for residents' intake in the disassembly sites (Table 2), this finding was consistent with the dominant level of low-brominated PBBs observed in the soil and e-waste residue samples (Zhao et al., 2008); and no PBB209 was detected in the sampled foods. Human recycling operations (e.g. melting of cable coating at high temperature) and chemical or biological degradation could have been responsible for such observations (US ATSDR, 2004; POPRC, 2007a).

4.2. *PBDEs*

The data showed that the intakes through rice consumption had the highest PBDEs levels (90.9 ng day^{-1}) for the residents living near the disassembly sites in Table 3. These findings are not surprising in that, Deng et al. (2007) found that high concentrations of PBDEs were detected in the atmosphere of another large e-waste recycling site-Guiyu Town, Guangdong Province, China, and vegetation (such as rice and vegetables) can accumulate PBDE through both particulate-bound and gaseous depositions from the polluted atmosphere (St-Amand et al., 2007). Moreover, the quantity of rice intake (310 g day^{-1}) was highest in these selected foods by local residents, the two factors can explain the finding that the highest PBDEs intake through rice consumption observed in the study.

PBDE47 was found to be the most predominant congener for the total PBDEs intake in the study sites, similar findings were also reported in Finnish, American and Swedish market baskets study on dietary intake (Kiviranta et al., 2004; Schecter et al., 2004; Darnerud et al., 2006), for example, PBDE47 accounted for 48% of the total PBDEs intake in Finnish study. PBDE47 was almost detected in all of the selected food samples, which can support the finding that PBDE47 was the primary intake contributor for the total PBDEs intake in the study.

As shown in Table 3, PBDE209 were detected in more than 60% of the pork and chicken samples, which accounted for 8.4% of the total PBDEs intake. Such a finding is not surprising at all. According to the World Health Organization (WHO, 1994b, 1997), the annual global consumption of PBDEs as flame retardants (and for other purposes as well) is 40,000 tonnes, of which *deca*-BDE (i.e., PBDE209) accounts for as much as 70%. Furthermore, many PBDE-containing plastics and polyurethane foams were once widely used in electrical or electronic products that are now referred to as "end-of-life" e-waste (POPRC, 2007b). High levels of PBDE209 were measured in all of the soil samples (192.38 ng g^{-1} dw) and the e-waste stuffing powder sample (4.19×10^3 ng g^{-1} dw) collected from the disassembly sites (Zhao et al., 2008). These findings in the last study tend to support the notion that PBDE209 through complex biogeochemical processes could eventually be bioaccumulated in food chains. In their study, Schecter et al. (2004, 2006) made a similar observation finding that PBDE209 also detected in many meat products in US (such as chicken breast, and pork). What's more, PBDE209 was a major contributor in some food supplies (e.g. cheese), which accounted for more than 70% the total PBDEs in their study.

4.3. *PCBs*

The data in Table 4 show that PCBs intake by local residents living near the disassembly sites had higher levels than those in the control site, which can be used to support the speculation that PCBs have entered into the food chain, especially due to their highly bioaccumulative and persistent characters in the environment (Hardy, 2000; McDonald, 2002). Among the three PHAH subfamilies, PCBs were found as the most predominant pollutants in food samples collected from the disassembly sites. PCBs had been widely used as coolants and insulators in electrical capacitors and transformers, and as plasticizers in paint and rubber sealant (Safe, 1994). Recent studies by Zhao et al. (2006, 2007, 2008) suggested that obsolete transformers and electrical waste are important sources for the emission of PCBs into local environments, high level of PCBs were observed in the soil (152.9 ng g^{-1} dw) and e-waste residue samples (680 ng g^{-1} dw), in addition, PCBs were also found to be the most highest levels pollutants among the three PHAHs in these environmental matrices. These findings in the last studies further supported the notion that PCBs were the dominant pollutants in food samples from the disassembly sites. PCB138 was the most predominant contributors for dietary intake of PCBs in the disassembly sites (Table 4), which is consistent with the finding in soil collected from the same sampling localities (Zhao et al., 2008).

4.4. *Domestic and international comparison*

To further appreciate the intake levels of the PHAHs by local residents in the study localities, the estimated TDIs of the three PHAHs subfamilies in the present study were conducted to compare with those reported recently for districts located in other countries. As shown in Table 5, the estimated TDIs of PBBs in the disassembly sites (385.5 ng day^{-1}) was 3 times more than those reported on general USA population (120 ng day^{-1}), and was within the range from 360 to 36,000 ng day^{-1} observed in the Michigan study, in which a widespread contamination of farm products by PBBs was occurred (WHO, 1994a). The estimated TDIs of PBDEs in the disassembly site (195.9 ng day^{-1}) seems to be somewhat higher than those reported in other countries (23–114 ng day^{-1}); the estimated TDIs of PBDEs (88.1 ng day^{-1}) in the control site was comparable to the above-mentioned values. Table 5 also shows that the estimated TDIs of PCBs and TEQs in the disassembly site were also higher than these reported values. By and large, although the estimated TDIs for the PHAHs

under study were lower than these reference doses recommended by WHO (or Health Canada), they were obviously higher than those observed in other places listed in the literature, thus suggesting that residents living around the disassembly site have been exposed to higher levels of PHAHs than those places listed in Table 5, and might be at greater health risk. Therefore, further research is needed into the long-term health impacts of chronic exposure to PHAHs for those Chinese residents who spend much of their time around an e-waste disassembly site.

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