HUMAN EXPOSURE TO PCBS IN ONE ELECTRONIC WASTE RECYCLING AREA OF CHINA

Xing GH[1], Chan JKY[1], Xu Y[2], Liang Y[3], Chen LX[4], Wu SC[1], Wong MH[1,*]
[1]Croucher Institute for Environmental Sciences, and Department of Biology, Hong Kong Baptist University, Kowloon Tong, Hong Kong, China; [2]State Key Laboratory of Freshwater Ecology and Biotechnology, Institute of Hydrobiology Chinese Academy of Sciences, Wuhan 430072, China; [3]Luqiao Institute of Traditional Chinese Medicine, Taizhou 318500, China; [4]Luqiao Center for Disease Control and Prevention, Taizhou 318500, China.
Author for correspondence: MH Wong. mhwong@hkbu.edu.hk

Abstract
Taizhou is an electronic waste recycling site with a relatively high PCB contamination in China. In this study, food, air and human samples were collected and PCB levels were analyzed to determine the exposure levels of PCBs for local residents. In addition to exposure to PCBs via food consumption, inhalation exposure is another important exposure pathway for the local people, and it was determined that they would be exposed to 54 ng PCBs/day through inhalation. For e-waste workers, inhalation of PCBs at the workplace was significantly higher. The mean concentrations of total PCBs in human milk, placenta and hair from Taizhou were 363 ng/g lipid, 224 ng/g lipid, and 386 ng/g dry wt, respectively, which were much higher compared to other studies. In terms of TEQ value for hair samples, dioxins contributed to 86% of the total TEQ level, whereas dioxin-like PCBs were the most abundant components for placenta and milk.

Introduction
E-waste (electrical and electronic waste) is a potential source for POPs, and a number of investigations have been undertaken with regards to exposure assessment.[1-3] Taizhou is a main e-waste recycling site in China with a relatively high level of PCBs due to the disassembling and recycling of a huge amount of transformers and capacitors.[4] Crude methods such as mechanical shredding, open burning, and acid leaching are commonly used in processing e-waste in this area, leading to the release of hazardous chemicals into the environment, and their subsequent accumulation into the food chain, which may impose potential human health risks. [1, 5]

The consumption of contaminated food is an important route for human exposure to PCBs, which is believed to contribute to more than 90% of the total exposure for the general population. [6-8] A number of studies have analyzed PCB levels in food, which mainly focused on meat and fish consumption in developed countries. [6, 9] A typical diets for Chinese contain a large amount of vegetables because of low level of living standard. However, there is a lack of information related to PCB exposure via consumption of vegetables.

Inhalation exposure and dermal contact are also possible exposure routes, especially for workers at transformer disposal sites. There is a need to assess human exposure and the potential adverse health effects of people engaged in e-waste recycling. The major objectives of this study were to investigate PCBs concentrations in food, air and also in human samples of the e-waste recycling area; and to evaluate human exposure to PCBs, via food consumption and inhalation exposure for workers and local residents.

Materials and Methods
All food items including fish (freshwater and marine fish), shellfish, meat, vegetables were sampled from the field or local markets. Samples were stored in an ice box and transported to the laboratory. For fish, the flesh together with skin, was used for the analysis. For vegetables, samples (excluding roots) were peeled and washed with tap water, followed by Milli-Q water. All the food samples were freeze-dried, pooled and homogenized by grounding into powder prior to extraction.

Air samplers (XQC-15E, Jintan, China), placed at 1.2 m above the ground, were used to collect gaseous and particulate samples at a flow rate of approximately 1.5 l/min. In total, twenty air samples were colleted at the workplace and residential area.

Twenty-five sets of human samples (including milk, placenta and hair) in Taizhou were collected. Likewise 25 sets were obtained from Lin'an, which is more than 200 km away from Taizhou, as the control site. Milk samples were either collected by using a breast pump or expressed manually to a 100 ml solvent-rinsed Pyrex bottle with a Teflon lined cap. Whole placentas were collected by the local gynecologists. The hair of breastfeeding mothers, near the scalp and from the nape of the neck, was collected using stainless steel scissors. They were wrapped in aluminum foil and placed into an acetone-washed reagent bottle. After delivered to the laboratory, placenta and human milk samples were froze dry, and hair samples were rinsed by water with 1% detergent, RO water and MQ water, dry in oven with 70 °C. All samples were kept frozen at -20 °C until analysis.

All the samples were extracted using 100 ml mixture of acetone and n-hexane (1:1, v/v) at 75 °C for 18h. Multilayer silica gel and florisil were used for clean-up. A total of 37 PCB congeners (PCB-18, 28, 37, 44, 49, 52, 70, 74, 77, 81, 87, 99, 101, 105, 114, 118, 119, 123, 126, 128, 138, 151, 153, 156, 157, 158, 167, 168, 169, 170, 177, 180, 183, 187, 189, 194 and 199) for food and air samples, and 23 PCB congeners (PCB-28, 52, 77, 81, 99, 101, 105, 114, 118, 123, 126, 128, 138, 153, 156, 157, 167, 169, 170, 180, 183, 187 and 189) for human samples, both including twelve dioxin-like PCBs and six indicator PCBs, were analyzed by GC-MS. A questionnaire, designed to obtain food consumption data in the local area, was used as the basis to interview the donating mothers and to collect statistical information. According to the questionnaire, the typical diet in Taizhou contained higher amounts of vegetables and cereal than meat and fish (Table 1).

Table1 Food consumption patterns for Taizhou residents

Food groups	Mean consumption (g/week)
Cereal and cereal products	2321
Vegetables	3380
Fish and seafood	620
Meat, egg and their products	458
Fruits	5973
Dairy products	725

Results and Discussion

The average levels of total PCBs (wet weight basis) were 388, 34.9, 0.52, 2.72, and 2.76 ng/g in freshwater fish (from fish pond), freshwater fish (from market), marine fish, shellfish and leafy vegetables, respectively. None of the fish samples were found to exceed the US FDA Action Limit (2.0 μg/g, wet wt). Significantly higher concentrations of PCBs were detected in freshwater fish from fish pond than those from the markets. Based on the food consumption survey, the average daily intake of PCBs for Taizhou mothers was 17.92 pg WHO-TEQ/kg body wt/day, which was much higher than the WHO's tolerable daily intake (1-4 pg/kg body wt/day). However, it must be pointed out that the data was based on the PCB levels in uncooked food, whereas cooking can decrease the levels of POPs in food in some condition.[10] Bioavailability of PCBs during food digestion and absorption, which is an important factor for effective exposure estimation, was also not taken into consideration. [11, 12] Thus, dietary intake of PCBs may be overestimated to a certain extent in this study.

PCBs levels in gas and airborne particles from the workplace and residential area of Taizhou were also analyzed. The inhalation exposure in the workplace and residential area were 336 and 54 ng PCBs/day, respectively, contributing 57% and 18% to the total body loading (i.e. food and inhalation exposure) of local residents.

The mean concentrations of total PCBs in human milk, placenta and hair samples collected from Taizhou were 363 ng/g lipid, 224 ng/g lipid, and 386 ng/g dry wt, respectively. PCB concentrations in three types of human samples (hair, placenta and milk) from Taizhou were 7.6, 5.0 and 3.1 times, respectively, higher than those in the control site (Lin'an). In terms of TEQ value for hair samples, dioxins contributed to 86% of the total TEQ level, but for placenta and human milk, dioxin-like PCBs were the most abundant component, contributing to 82.5% and 91.6% of the total TEQs, respectively. Taizhou topped the list when comparing the PCB levels in human milk with other comparable studies, whereby all samples were collected after 2000(Fig. 1).[13-22] Elevated levels of PCBs in environmental and human samples showed severe environmental threat in Taizhou, caused by e-waste recycling activities. Health effects and risk assessment for PCBs in Taizhou should be carried out in further studies.

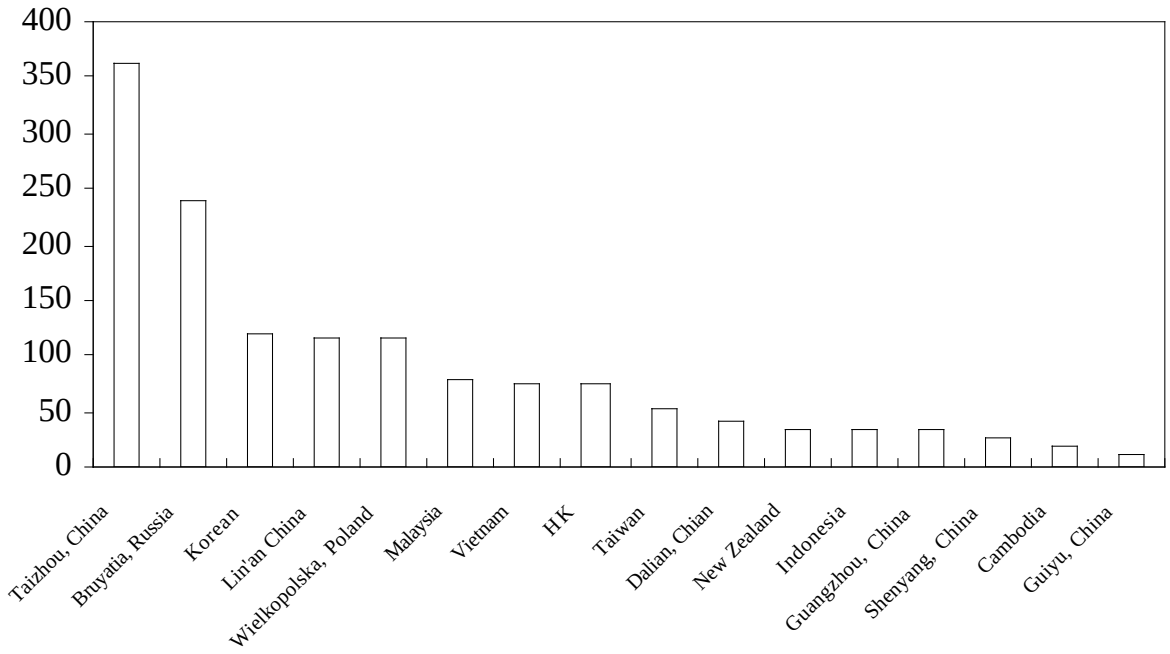

Figure 1 Comparison of PCB levels in human milk of different countries/cities (ng/g lipid)

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