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Health risk assessment of migrant workers' exposure to polychlorinated biphenyls in air and dust in an e-waste recycling area in China: Indication for a new wealth gap in environmental rights

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ABSTRACT

Migrant workers who work and live in polluted environment are a special vulnerable group in the accelerating pace of urbanization and industrialization in China. In the electronic waste (e-waste) recycling area, for example, migrant workers' exposure to pollutants, such as PCBs (polychlorinated biphenyls), is the result of an informal e-waste recycling process. A village in an electronic waste recycling area where migrant workers gather was surveyed. The migrant workers' daily routines were simulated according to the three-space transition: work place–on the road–home. Indoor air and dust in the migrant workers' houses and workplaces and the ambient air on the roads were sampled. The PCB levels of the air and dust in the places corresponding to the migrant workers are higher than those for local residents. The migrant workers have health risks from PCBs that are 3.8 times greater than those of local residents. This is not only caused by the exposure at work but also by their activity patterns and the environmental conditions of their dwellings. These results revealed the reason for the health risk difference between the migrant workers and local residents, and it also indicated that lifestyle and economic status are important factors that are often ignored compared to occupational exposure.

1. Introduction

Polychlorinated biphenyls (PCBs) are a group of chlorinated compounds widely used in industrial and commercial areas as dielectric fluid in transformers and capacitors; they are also used in flame retardants, plasticizers, resins, paints, sealants for wood and cement surfaces, and industrial lubricating (Cachada et al., 2009). Because of their biological toxicity, linked to teratogens, carcinogens and mutagens (Cogliano, 1998; Nicolopoulou-Stamati and Pitsos, 2001), they have been banned and listed to the 12 worst offenders in the Stockholm Convention on Persistent Organic Pollutants in 2001 (Lallas, 2001). Since then, increasing attention has been directed to environmental pollution and the adverse human health consequences caused by PCBs. In e-waste recycling areas in underdeveloped countries, because of primitive dismantling methods, such as open burning, metal melting and acid dipping (Hicks et al., 2005; Leung et al., 2008), a large amount of toxic contaminants are releasing into the surrounding environment causing adverse human health consequences (Chen et al., 2010; Shen et al., 2009a; Shen et al., 2009b; Tang et al., 2010). Some studies have reported human body burdens in e-waste recycling areas (Taizhou and Guiyu in China) where PCB levels in breast milk, serum, the liver, lungs, and umbilical cord blood samples were significantly higher than those from a reference group (Bi et al., 2007; Xing et al., 2009; Zhao et al., 2009). The health risk of exposure to PCBs from e-waste recycling area is concerning.

Among the current published studies, many focus on the dietary intake of PCBs; due to their lipid solubility and the absence of a metabolic pathway in organisms, PCBs tend to bioaccumulate along trophic chains (Borja et al., 2005; Park et al., 2007). Except for dietary ingestion, inhalation constitutes a significant exposure pathway (Currado and Harrad, 1998). Harrad and Diamond (2006) recognized that the indoor environment is a potentially important vector of exposure for PCBs, according to their series of studies (Hazrati and Harrad, 2006). However, only a few studies reported the air and dust exposure of PCBs in e-waste recycling areas (Tue et al., 2013; Xing et al., 2009).

Cancer is the leading killer of human beings. Environmental factors and occupational exposure contribute significantly to the occurrence of cancer (Parkin, 2011). More than half of all cancers and 63% of cancer deaths occur in low- and middle-income countries (Espina et al., 2013).

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Exposure to most carcinogens tends to be greatest in the most disadvantaged segments of the population (Kogevinas et al., 1997). In the USA, former President Bill Clinton signed Executive Order 12898, the "Federal Actions to Address Environmental Justice in Minority Populations and Low-Income Populations", to call for environmental equity. However, with most of the e-waste from developed countries destined for developing countries (The Basel Action Network and Silicon Valley Toxics Coalition, 2002), populations of residents in e-waste recycling areas have been suffering from environmental hazards. Local residents, mothers and children are vulnerable groups in e-waste recycling areas (Song and Li, 2014).

However, there is also a special and vulnerable group — migrant workers. In the process of urbanization and industrialization in China, a large surplus of labour forces streamed to cities. Because of cheap labour and high interest, coupled with weak environmental regulation, many high pollution industries have arisen. In this setting, groups of migrant workers have appeared. They are engaged in labour-intensive industries, suffering from environmental and occupational exposures. At the end of 2014, the total number of migrant workers who left their homes to work in other cities was 168.21 million, an increase of 1.3% from 2013 (China, 2015b). Moreover, since 1978, the floating working population in China has increased annually (Zhu, 2007). Migrant workers are different from nine-to-five workers and ordinary residents. They cannot easily enjoy social rights including environmental rights. Among the numerous polluting industries is the electronic dismantling industry. The city of Taizhou in eastern China is one of the world's biggest e-waste recycling centres. The most intensive e-waste recycling occurs in the town of Fengjiang where more than 40 factories are engaged in e-waste recycling, employing approximately 40 000 people (Ma et al., 2008). Except for the formal factories, there are many informal factories and family-run workshops, which are difficult to count. An overwhelming majority of dismantling workers are migrant workers. Through our survey, we found that the migrant workers typically live in rental housing, which has been abandoned by local residents, or they settle in temporary housing. Their house is small and humble where they cook and sleep. They do not take any proper protective measures when they are working; they only use gloves. The medical college at Shantou University in Guangdong province performed physical examinations of migrant workers in Guiyu, another e-waste recycling centre in China. It found that 88% of migrant workers suffer from skin, nervous system, respiratory system and digestive system diseases (Qin et al., 2005). As for the local residents in Taizhou, those that profited most from the e-waste dismantling trade, many chose to move to other large cities or went abroad in search of a better living environment. Many of the remaining local residents do not work in e-waste dismantling workshops. Most run the e-waste dismantling factories or are self-employed, and a small portion are engaged in farming.

This study focuses on the non-dietary exposure of migrant workers in an e-waste recycling area. There are three reasons for focusing on non-dietary exposure: i) In terms of dietary exposure, there is no substantial difference between migrant workers and local residents, due to each having the same food source; ii) Regarding inhalation exposure, migrant workers encounter occupational exposure in the workplace and are also exposed to pollutants in their small dwellings; iii) Considering dust ingestion, similar to inhalation exposure, migrant workers are exposed to pollutants both in their workplaces and homes.

This study was specifically concerned with the health risk of migrant workers and a comparison was made between migrant workers and local residents in an e-waste recycling area. We simulated the migrant workers' daily routines according to the three-space transition: work place–on the road–home, and assessed their exposure risk to PCBs through outdoor and indoor air inhalation and indoor dust ingestion.

The principal objectives of this study were i) to evaluate migrant workers' exposure to PCBs via a non-dietary pathway; ii) to clarify the health risk differences between migrant workers and local residents; and iii) to determine the reasons causing the risk differences.

2. Materials and methods

2.1. Sample locations

We selected the e-waste recycling city of Taizhou in Zhejiang province in China as the research area. To know the concentration of PCBs in the different places included in the migrant workers' and local residents' activities (details in Table 1), three types of sampling locations were selected for this study: e-waste recycling factories (n = 3), the main road (n = 2), and houses (n = 12). We sampled the indoor air and dust in workshops, houses, and the ambient air on the main road. For ease of reference, each sampling site has been assigned a numerical identifier. These are listed in Supplementary Information (SI) Table S1. The locations of sampling sites are shown in Fig. 1.

2.2. Air sampling

Seventeen air samples were collected using a SIBATA high-volume sampler (HV-1000R) with a quartz fibre filter (QFF, pore size 0.3 μm, 85 g ± 4 g/m^2, 8 × 10 in.) and a pre-cleaned polyurethane foam (PUF, 0.022 g/cm^3, Ø90 × 50 mm) between October 9 and November 6, 2014. Sample flow rates were typically 0.7–0.8 m^3 min^{-1}. Three indoor air samples from recycling workshops in different factories, two outdoor air samples from the main roads, and twelve indoor air samples form migrant workers' houses (n = 6) and local residents' houses (n = 6) were investigated. The ambient air samples and workshops air samples were collected for a periods of approximately 24 h. The indoor air samples of migrant workers' and residents' houses were collected for 12 h. For details about the pre-treatment of the QFF and PUF see SI.

2.3. Indoor dust sampling

Thirteen indoor dust samples (dismantling workshops (n = 3), migrant workers' houses (n = 5), local residents' houses (n = 5)) were collected using a polyethylene brush and a paper from the surfaces of furniture, electric fans, windows and walls. Then they were passed through a 100-mesh stainless steel sieve stored in an opaque polyethylene zip bag, and then stored at −20 °C until analysis. Before sampling, household residents were told not to dust the house for three weeks.

2.4. Sample extraction and cleanup

Each sample was spiked with a surrogate standard and Soxhlet extraction, and then cleaned using a florisil/anhydrous sodium sulphate column (Luo et al., 2014; Shen et al., 2008). For details see SI.

2.5. Instrumental analysis

Analyses of all of the samples were performed using an Agilent 7890A GC equipped with an Agilent 5975C mass spectrometer (MS) and auto sampler. The PCBs were quantified by using customized calibration standards prepared from an AccuStandard Aroclor 1242 plus Aroclor 1254. An Agilent 19091S-433 capillary column (30 m × 0.25 mm × 0.25 μm) was used with the following temperature protocol: initial temperature 80 °C for 2 min; 8 °C min^{-1} to 196 °C; 2 °C min^{-1} to 228 °C; 10 °C min^{-1} to 250 °C, and then held for 12 min. 57 individual PCB congeners were quantified in this study. They were PCB6, 7, 8, 16, 17, 18, 19, 22, 24, 25, 26, 28, 31, 32, 33, 37, 40, 41, 42, 44, 45, 49, 52, 56, 60, 64, 66, 70, 74, 82, 83, 85, 87, 97, 99, 100, 101, 108, 110, 118, 128, 129, 136, 138, 137, 141, 146, 149, 153, 159, 170, 175, 177, 178, 180, 185, 187. Details about the analyses can be found in the SI.