Environmental Pollution 230 (2017) 838–848

Contents lists available at ScienceDirect

Environmental Pollution

journal homepage: www.elsevier.com/locate/envpol

Decreased lung function with mediation of blood parameters linked to e-waste lead and cadmium exposure in preschool children☆

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A R T I C L E I N F O

Article history:
Received 23 January 2017
Received in revised form
5 June 2017
Accepted 5 July 2017

Keywords:
Lead
Cadmium
Hemoglobin
Lung function
E-waste
Preschool children

A B S T R A C T

Blood lead (Pb) and cadmium (Cd) levels have been associated with lower lung function in adults and smokers, but whether this also holds for children from electronic waste (e-waste) recycling areas is still unknown. To investigate the contribution of blood heavy metals and lung function levels, and the relationship among living area, the blood parameter levels, and the lung function levels, a total of 206 preschool children from Guiyu (exposed area), and Haojiang and Xiashan (reference areas) were recruited and required to undergo blood tests and lung function tests during the study period. Preschool children living in e-waste exposed areas were found to have a 1.37 μg/dL increase in blood Pb, 1.18 μg/L increase in blood Cd, and a 41.00 × 10^9/L increase in platelet counts, while having a 2.82 g/L decrease in hemoglobin, 92 mL decrease in FVC and 86 mL decrease in FEV_1. Each unit of hemoglobin (1 g/L) decline was associated with 5 mL decrease in FVC and 4 mL decrease in FEV_1. We conclude that children living in e-waste exposed area have higher levels of blood Pb, Cd and platelets, and lower levels of hemoglobin and lung function. Hemoglobin can be a good predictor for lung function levels.

1. Introduction

Electronic waste (e-waste) is defined as any discarded, obsolete, or broken electrical or electronic devices or products nearing the end of their useful life, which has become the largest growing amount of waste in the world (Zhang et al., 2012; Grant et al., 2013; Zeng et al., 2016a,b,c). It was estimated that global e-waste generation was 41.8 million tonnes in 2014 and increases at the rate of about 11% annually (Breivik et al., 2014; Heacock et al., 2016; Wang et al., 2016a,b). Approximately 70% of e-waste is illegally exported or dumped by developed countries to China (Zhang et al., 2012; Awasthi et al., 2016; Wang et al., 2016a,b). E-waste cannot be regarded or treated like any other type of waste because it contains blends of hazardous metals (60%), plastics (30%), and other materials (10%) (Widmer et al., 2005; Wong et al., 2007a,b; Chen et al., 2009; Wittsiepe et al., 2015; Wang et al., 2016a,b). Heavy metals can not only be degraded into less hazardous end products, but can also be taken up by environmental media such as air, dust, soil, water, and sediment (Wong et al., 2007a,b; Guo et al., 2009; Song and Li, 2014), and accumulate in the human body through inhalation, ingestion, and dermal absorption (Song and Li, 2015; Zeng et al., 2016a,b,c; Zhang et al., 2016). Heavy metals such as lead (Pb) and cadmium (Cd) mainly enter the human body through respiration and concentrate in tissues and organs via the blood circulation. They are deposited in the bronchioles and alveoli of the airways in the form of aerosols, dust and steam. Heavy metal exposure may contribute to increased oxidative stress, disruption of barrier mechanisms, inflammation and tissue destruction in the lungs (Kirschvink et al., 2006). Only a few studies have demonstrated that blood Pb and blood Cd levels were associated with lower lung function levels in adults. Whether this also holds for

☆ This paper has been recommended for acceptance by David Carpenter.
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http://dx.doi.org/10.1016/j.envpol.2017.07.014
0269-7491/

children (who are more susceptible) from e-waste recycling areas was not explored and therefore still unclear (Pak et al., 2012; Park and Lee, 2013; Oh et al., 2014).

With a 30-year history of e-waste disposal and recycling with little or no regulation, Guiyu has become one of the largest e-waste destinations and recycling areas in China and worldwide. About 70% of the e-waste imported or generated by China was processed in Guiyu (Wu et al., 2010; Chen et al., 2011), which leads to its highest level of e-waste pollution in the world (Huo et al., 2007; Ogunseitan et al., 2009; Wang et al., 2016a,b). Informal e-waste recycling and disposing process not only contributes to serious pollution but also threat to human health. Previous studies reported high levels of Pb and Cd concentrations in Guiyu compared to many other areas in $PM_{2.5}$ (Deng and Wong, 2006; Zeng et al., 2016b,c), dust (Leung et al., 2008; Yekeen et al., 2016), soil (Fu et al., 2008; Yekeen et al., 2016), water (Wong et al., 2007; Guo et al., 2009), and sediment (Wong et al., 2007a,b; Guo et al., 2009). Several cross-sectional studies demonstrated high levels of blood Pb and Cd were presented in Guiyu for years (Huo et al., 2007; Zheng et al., 2013; Zeng et al., 2016a,b,c; Lin et al., 2017). Strak et al. showed a significant associations between lung function levels of forced vital capacity (FVC) and forced expiratory volume in 1 s (FEV_1) with trace metals such as Fe, Cu, and Ni in $PM_{2.5}$ and PM_{10} (Strak et al., 2012). Nearly 76% of e-waste workers suffered from respiratory symptoms or diseases including dyspnea, cough, bronchitis, and asthma according to a survey conducted by the Associated Chambers of Commerce and Industry of India (Sharma, 2015). Recently, our study found that the levels of Pb and Cd both in $PM_{2.5}$ and in blood, as well as the prevalence of respiratory symptoms cough, dyspnea, phlegm and wheeze in preschool children (3-to-8-years of age) were higher in Guiyu compared to the reference areas (Zeng et al., 2016c). In addition, one of our previous studies demonstrated that there was no difference in FVC of primary school children aged 8–13 years old between the exposed and reference area (Zheng et al., 2013). However, FVC was significantly lower in Guiyu children compared to those from the reference area in the youngest age group (8–9 years). It seems like that younger children are the particular more sensitive and vulnerable population compared to older children and adults.

In view of the lack of reports concerning the association between blood heavy metal and lung function levels in younger preschool children from e-waste recycling areas, we recruited 206 preschool children aged 5–7 years from Guiyu (the exposed area), and Haojiang and Xiashan (the reference areas). We measured the blood parameter levels such as Pb, Cd, hemoglobin, platelet counts and performed spirometry to obtain FVC and FEV_1 lung function levels. This study aims to determine blood parameters such as blood Pb, Cd, hemoglobin and platelets, evaluate their effect on lung function levels, and offer a deeper understanding of the effect of living in e-waste exposed area on lung function levels.

2. Materials and methods

2.1. Study areas and population

The sampling site was located in Guiyu town (exposed area), Shantou city, in the southeastern coast of Guangdong province in China. Haojiang (the first reference area) is located 31.6 km to the east of Guiyu and Xiashan (the second reference area) is located 5.8 km to the southeast of Guiyu (Fig. 1) (Huo et al., 2007). There are similar demographic characteristics, life-styles, eating habits, and traffic conditions in these three areas. Haojiang and Xiashan were selected as the reference areas because they lack e-waste pollution. A total of 206 preschool children, 5-to-7-years old, were recruited from three kindergartens from Guiyu ($n = 100$), Xiashan ($n = 54$), and Haojiang ($n = 52$) during the period of November 2013 and December 2013. Participant received a general health questionnaire. All parents or guardians of the participants gave their written informed consent after receiving detailed explanations of the study and potential consequences prior to enrollment. This study protocol was approved by the Human Ethical Committee of Shantou University Medical College, China.

2.2. Physical growth and development test

Physical growth and developmental parameters such as body height, body weight, and chest circumferences were measured at the time of blood sample collection. Height and weight were measured using a weight and height scale (TZ120; Yuyao Balance Instrument Factory, Yuyao, China). Children were required to remove their shoes, take off their coat, and maintain a certain standing posture prior to being measured. All measurements were carried out by a trained physician (Liu et al., 2011).

2.3. Spirometry

Spirometry was conducted with a portable spirometer (Jiangsu Jintan Medical Instrument Factory, Model DF-II, Jintan, China), using standardized procedures following ATS-criteria (Miller et al., 2005). Participants practiced the use of the mouthpiece with the spirometer until they felt comfortable under the guidance of the field physician. Results of three readings were recorded, and the highest reading of forced vital capacity (FVC) and forced expiratory volume in 1 s (FEV_1) was used in the analysis.

2.4. Questionnaire

We collected information on potential routes of exposure to e-waste, lead and cadmium, as well as general demographic and health parameters with a general questionnaire (Zeng et al., 2016c). The basic information collected by the questionnaire included age; gender; birth weight; family member daily smoking; socioeconomic status such as parental education levels and family income levels; eating habits such as eating daily products, eating preserved eggs, and eating canned food; behavior habits such as biting fingers or nails, biting pencils or erasers, biting toys, washing hands before eating, contact with e-waste, and outdoor daily play time; home location information such as distance from home to a road, and home close to e-waste within 50 m; and other factors such as ventilation of house, closed windows, and home used as workplace. The parents or guardians of the children recruited in this study completed the questionnaire.

2.5. Blood sample analyses

Venipuncture was performed by nurses, and blood was collected and stored in metal-free tubes at minus 20 °C until analysis. Hemoglobin, hematocrit, platelet counts, thrombocytocrit, and red blood cell distribution width (RDW) were measured using an automatic hematology analyzer (Sysmex XT-1800i). RDW was considered a biomarker for nutritional status because an increased RDW is associated with nutritional deficiency (Grant et al., 2013). Blood Pb and blood Cd determinations were performed by graphite furnace atomic absorption spectrophotometry (Jena Zenit 650). The detailed procedure for measuring blood Pb and blood Cd was previously described in our previous studies (Guo et al., 2010; Zeng et al., 2016c). Briefly, 100 μL blood and 900 μL of 0.5% nitric acid for BPb, or 200 μL blood and 800 μL of 5% nitric acid for BCd were placed into tubes. The mixture was immediately shaken and then allowed to digest for 10 min. Unlike BPb measurements, after