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Exposure risks of noise and heavy metals in dismantling lines for recovering waste televisions

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ABSTRACT

Quantities of waste televisions have been generated in the world and manual dismantling was chosen to treat waste televisions. Therefore, exposure risks of pollutants in manual dismantling process should be concerned. In this paper, exposure risks of noise and heavy metals in full manual dismantling line and semi-automatic dismantling line for recovering waste televisions were studied. The highest noise levels exposed in full manual dismantling line and semi-automatic dismantling line were 92.3 dB(A) and 87.9 dB(A), which brought harm to workers. The highest concentrations of total suspended particulates, particulate matter 10, and particulate matter 2.5 exposed in the workshop of full manual dismantling line were 2425 $\mu g/m^3$, 1624 $\mu g/m^3$, and 1184 $\mu g/m^3$. The corresponding values in semi-automatic dismantling line were 1221 $\mu g/m^3$, 851 $\mu g/m^3$, and 602 $\mu g/m^3$. These values were ten times higher than the standard values in Ambient Air Quality Standard. The concentrations of lead in the air caused negative effect to workers, even chronic risk. The highest concentrations of zinc and lead exposed in the ground dust of the workshop reached 4868 mg/kg and 5226 mg/kg, almost ten times higher than the allowed concentration limit. Concentrations of zinc and lead exposed in surface soil of flower bed reached 683 mg/kg and 468 mg/kg. The results indicated noise and heavy metals exposures in dismantling process of waste televisions were harmful. However, Semi-automatic dismantling made a certain progress on environmental performance than full manual dismantling for treating waste televisions. Additionally, measures for controlling the exposure risks of noise and heavy metals were proposed for improving semi-automatic dismantling such as the closed and automatic transport system. This paper provided environmental information about the dismantling process for recovering waste televisions. It also supported scientific information for the government to improve the recovery process of waste televisions on cleaner production.

1. Introduction

Quantities of waste televisions (TVs) have been generated in the world (Ongondo et al., 2011). The number of waste TVs in China reached 60 million only in 2013. Treatment of waste TVs had brought high pressure to solid waste management and resource recycling. Waste TVs are comprised of cathode ray tube (CRT), printed circuit board (PCB), plastic shell, and other accessories (Fig. 1). In the eyes of businessman, metals in the comprised materials were the profits that caused them to treat waste TVs. However, heavy metals and organics in the comprised materials of waste TVs were environmental burden if waste TVs were treated in improper ways (Rocchetti and Beolchini, 2014; Guo et al., 2015; Deng et al., 2014).

Incentive policies have been implemented by Chinese government to encourage the enterprise to treat e-waste (State Council, 2012; Zeng et al., 2013). For instance, about 13.5 dollars subsidy was allowanced to the enterprise for treating per waste TV. Thus, certified enterprises for treating e-waste were established with the support of government (Qu et al., 2013). Although some technologies had been reported for treating the glass of waste CRT (Jonathan et al., 2005; Grause et al., 2014; Ling and Poon, 2011), there were

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Fig. 1. Waste TVs and the contained components.

little advanced technologies to dispose waste TVs besides manual dismantling. Due to the low labor cost in China, full manual dismantling was chosen to treat waste TVs. Human health and environmental risks in the sites of manual dismantling of e-waste in China had been reported (Lim and Schoenung, 2010; Ruan et al., 2012; Leung and Wong, 2008). However, little reports were about the risks assessments in dismantling lines of waste TVs, especially noise and heavy metals exposures (An et al., 2014).

In previous work, heavy metal exposures in particulate matter 2.5 (PM2.5) and particulate matter 10 (PM10) of full manual dismantling (FMD) of waste TVs in a certified enterprise were studied (Fang et al., 2013). It reported that metal exposures in PM10 of the workshop was safe. In PM2.5 of the workshop, metal exposures would bring health risk. However, the certified enterprise was managed by the Environmental Protection Department of Shanghai City and with the goal of setting an example of the recycling process of e-waste, not for profiting from recovering e-waste. Treatment capacity of waste TVs in the enterprise was much less than other certified enterprise whose aim was to profit from recovering e-waste. Therefore, the information published in previous work express inaccurate exposure of heavy metals in manual dismantling of waste TVs. For supplementing fullness data for the government to improve cleaner production of waste TVs dismantling, heavy metal exposure risks in the for-profit enterprise of recovering waste TVs urgently need to be investigated. Meanwhile, noise exposure also needs to be concerned.

In this paper, noise and heavy metal exposures in FMD line and semi-automatic dismantling (SAD) line of recovering waste TVs were studied. And, measures of controlling the exposures of noise and heavy metals were proposed. This paper provided environmental data of the dismantling process for recovering waste TVs. It also contributed to the government and enterprise to construct cleaner production for recovering waste TVs.

2. Materials and methods

Dismantling lines for recovering waste TVs in a for-profit e-waste treatment enterprise were the monitoring objects. Exposures of noise and heavy metals in the two line were investigated.

2.1. FMD line and the SAD line

In 2013, FMD line was employed in the enterprise. The flowchart of FMD line was given in Fig. 2a. It included manual handing, plastic shell remove, accessories cutting, PCBs removal, and CRT treatment. Simple dust collector and rough safeguard were employed to protect worker's safety. In 2014, FMD line was renovated to SAD line in the enterprise for improvement of environment performance. Automatic transport system was employed in SAD line (presented in Fig. 2c) and negative-pressure dust collected system was installed above the conveyors. Meanwhile, treatment of CRT was placed in a closed room and an automatic cutter was adopted for crushing CRT. Bag-type dust collector was allocated to the closed room.

2.2. Noise monitoring

An integrating sound level meter (AWA 5610B) and an octave filter (AWA 5722) were employed to monitor noise levels of FMD line and SAD line in their running state. Monitoring positions for FMD line were located at the storing area, around FMD line, and at the boundary of the workshop. More details of positions were presented in Fig. 2b. Noise monitoring positions for SAD line were located at the storing area, in closed room for treating CRT, at dust collector, around the SAD line, and at the boundary of the workshop (Fig. 2d). The sound level meter and octave filter were placed 1.2 m above the ground and 1 m away from the monitoring object. Three values of noise level were recorded in different positions and the average level was adopted.

2.3. Monitoring of heavy metal exposure

A middle volume air sampler (flow rate: 0.120 m^3/h) was used to collect Total Suspended Particulates (TSP), PM10 and PM2.5 samples during the course of working days. For FMD line, the sampling positions were located in the center of the line, at the entrance and exit of the workshop. For SAD line, the sampling positions were located in the center of the line, in closed room for treating CRT, and at the entrance and exit of the workshop. The detailed positions were marked in Fig. 2b and d. The sampler was placed about 1.7 m above the ground. Sampling periods lasted from May to October of 2013 and from March to July of 2014. Every sampling time lasted for 8 h in working time once a month. During sampling period, the range of average ambient temperature and relative humidity were 5–35 °C and 53–80% respectively. Concentrations of TSP, PM10 and PM2.5 were calculated by Equation (1) (Baptista and Miguel, 2005):

$$C_{(TSP,\ PM10, PM2.5)} = \frac{M_S - M}{V} \quad (1)$$

where M_S was the weight of the filter paper after sampling (mg), M was the weight of the filter paper before sampling (mg), V was the volume of gas flow (m^3).

Samples of ground dusts were collected from the ground inside and outside of the workshop by a small broom. Samples of surface soils were collected from the flower bed in the enterprise. The enterprise was established in an industrial park and there was no farming land around.

The samples (TSP, PM10, PM2.5 samples together with the filter; dust: 0.5 g; soil: 0.50 g respectively) were soaked by HNO3 (5 ml, 69%), HCl (15 ml, 36%), and H_2O_2 (2 ml, 30%) for 12 h. Then the mixtures were heated progressively to 190 °C to near 6 ml. After it was cooled, the solution was filtered into 100 ml volumetric flasks. Finally, concentrations of metals were detected by the method of inductively coupled plasma mass spectrometry (ICP-MS, Nexion 300, PerkinElmer, U.S.) (Xue et al., 2012). For quality control, a blank test was also conducted with the same method.

For evaluating the risk of heavy metal exposed in the air of the workshop, risk assessment models from EPA (US) were employed