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HEAVY METAL CONCENTRATION OF SURFACE DUST PRESENT IN E-WASTE COMPONENTS: THE WESTMINISTER ELECTRONIC MARKET, LAGOS CASE STUDY

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Abstract

To evaluate the extent of heavy metals (Cd, Cr, Pb, Zn, Fe) contamination from e-waste, surface dust samples were collected from workshops (indoor), around the market areas (outdoor) and from a distance of about 100 metres away from the market area (control) of the Westminister Electronic market in Lagos, Nigeria. Aqua regia digestion was applied to the dust samples prior to determination of heavy metal by atomic absorption spectroscopy (AAS). The AAS analysis revealed mean concentrations in indoor dust (Pb 22.50, Cd 1.80, Fe 108.00, Cr 0.35 and Zn 295.50 mg/kg), outdoor dust (Pb 15.90, Cd 19.00, Fe 103.3, Cr 0.10 and Zn 213.00 mg/kg) and control dust (Pb 9.40, Cd -, Fe 62.00, Cr – and Zn 78.00 mg/kg). Although the result showed a relatively low contamination in general, it could be inferred that the increased concentration of heavy metals from the indoor electronic waste could be from the interaction of heavy metals in the e-waste components with the settled dust on them over time. The mean Cd and Zn concentrations in the indoor and outdoor dust samples were found to be above the New Dutch List optimum value for these metals. Risk assessment predicted that Cd and Zn in the e-waste have the potential to pose serious health risks to workers and local residents of Westminister area, especially children; and this underscores the urgent intervention by relevant government agencies.

Keywords e-waste, Heavy metals, Surface dust, Risk assessment

1. INTRODUCTION

E-waste broadly covers waste from all electronic and electrical appliances and comprises of items such as computers, mobile phones, digital music recorders/players, refrigerators, washing machines, televisions (TVs) and many other household consumer items (Sinha, 2007; Pinto, 2008]. E-waste products contain intricate blends of plastics and chemicals, which when not properly handled can be harmful to people and the environment (Leung, et al, 2006). The composition of e-waste is very diverse and differs in products across different categories. It contains more than 1000 different substances, which fall under 'hazardous' and 'non-hazardous' categories. The presence of elements like lead, mercury, arsenic, cadmium, selenium and hexavalent chromium and flame retardants beyond threshold quantities in e-waste classifies them as hazardous waste (http://www.cpcb.nic.in/Electronic%20Waste /Chapter1-2.html.)

Electronic waste or e-waste is one of the rapidly growing problems of the world. It is estimated that 20-50 million tons of electric and electronic waste is generated per year of which 75-80% is shipped to countries in Asia and Africa for recycling and disposal. In these countries recycling of e-waste is

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performed with limited and often no environmental or worker health precautions. Activities at these sites often pose harmful threats in the form of soil pollution leading to contaminated water and food as well as air contaminants affecting the health of the workers and children at these sites (Caravanos et al, 2011).

While over 80 per cent of the world's high-tech wastes lands up in land-fills in Asia and Africa, Nigeria is emerging as one of the top dumping grounds for toxic, chemical and electronic waste from the developed world (www.greendiary.com). According to the Basel Action Network (BAN), a Seattle-based environmental group, an estimated 500 shipping containers with a load equal in volume to 400,000 computer monitors or 175,000 large TV sets enter Lagos, Nigeria each month. As much as 75 percent of such shipments are classified as e-waste (www.ipsnews.net). The recycling, parts salvaging, distribution and the disposal of these discarded electronic devices are now creating a new set of environmental and public health challenges in Nigeria.

Dust is a significant environmental media that can provide information about the level, distribution, and fate of contaminants present in the surface environment (Leung et al, 2008). As the composition of settled dust is similar to atmospheric suspended particulates, it can be an indicator of pollutants such as heavy metal contamination in the atmosphere (Leung et al, 2008; Akhter et al, 1993]. The level of heavy metal concentration may be evaluated from the level of dust deposition per unit area and metal concentrations in the deposit (Krolak, 2000). Hence the level of heavy metal concentration in dust found within the lattices of electronic waste is evaluated in this study. This is because most e-wastes often contain dust particles embedded within their various components and as such poses health risks when dismantled and piled up in stores without proper disposal.

Humans can become exposed to heavy metals in dust through several routes which include ingestion, inhalation, and dermal absorption (Leung et al, 2008). In dusty environments, it has been estimated that adults could ingest up to 100 mg dust/day (Leung et al, 2008; Hawley, 1985; Calabrese, 1987). Children are usually exposed to greater amounts of dust than adults as a result of pica and play behaviour (Leung et al, 2008, Murgueytio et al, 1998). Exposure to high levels of heavy metals can result in acute and chronic toxicity, such as damage to central and peripheral nervous systems, blood composition, lungs, kidneys, liver, and even death. Lead levels in dust have been significantly associated with Pb levels in children's blood (Leung et al, 2008; Lanphear et al, 1997) and a blood lead level (BLL) greater than an intervention level of 10 μg Pb/dL has been associated with a decrease in IQ(Leung et al, 2008).

Two studies have demonstrated elevated body loadings of heavy metals (Huo et al, 2007) and persistent toxic substances (Bi et al, 2007) in children and e-waste workers, respectively, at Guiyu, China (Leung et al, 2008). Although there is paucity of data on post impact e-waste environmental studies in the Africa region, a recent study in Nigeria has demonstrated high concentrations of copper, nickel, zinc and lead in soils far in excess of European Union limits at e-waste dump sites in Lagos, Benin, and Aba cities in Nigeria (Nnorom, 2009). Contamination of plants and nearby surface waters in e-waste disposal sites by heavy metals was also reported in these sites (Nnorom, 2009). Another study showed that the mean concentration (mg/kg) of Cu and Pb in Printed Circuit Boards (PCB) of CPU and monitor of computers were found to be over 50 folds higher than the Toxicity Threshold Limit Concentration (TTLC) for the metals in electrical and electronic equipment in developed countries (Olubanjo, 2009). The excessively high concentrations of Cu and Pb in the components of the computers analyzed suggest that these used computers are hazardous wastes. Consequently, improper disposal of the PCBs of the CPU and monitors in the environment may pose serious risk to humans and the environment (Osibanjo, 2009).

The objectives of this study were to quantify the amount of heavy metal present in surface dust collected from outside casing and lattices of electronic wastes across workshops and environs in a popular electronic market in Nigeria (West Minister market) and to compare it with the New Dutch List optimum for metal pollution in soils. To estimate the potential health risk to adults and children via dust ingestion

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was also done.

2. MATERIALS AND METHODS

2.1. Study Area

Westminister Electronic Market is situated in Apapa Local Government Area of Lagos, Nigeria, close to the Lagos Tincan Island Port. Its location has made it an attractive point for disembarking and selling Used Electrical and Electronic Equipment (UEEE). The market has about 300 outlets where all types of UEEE are sold. Additionally, the market also has large storing facilities, which make it a big hub for storing UEEE before being redistributed to other markets or exported to neighbouring countries (Odeyingbo, 2011).

2.2. Sample Collection and Preparation

Three categories of dust samples were randomly collected between November 2009 and January 2010 during the dry season, when the prevalence of dust was expected to be high.

Dust samples were collected from the surfaces of printed circuit boards, plastic casings, cathode ray tubes and other internal and external components of e-waste across different stores within the market by careful brushing with plastic brushes into plastic containers. This was tagged indoor dust.

Surface dust was also collected randomly from bare ground across the market area outside the workshops. This was tagged Outdoor dust.

Surface dust was also collected from a place 100 meters away from the market area where heavy metal contribution from e-waste is not present. The samples were homogenized and mixed. This was used as control.

Each representative sample was stored in polyethylene bags which had been previously treated overnight with dilute HNO_3. They were then placed in dessicators to get rid of moisture and ground into fine powder. Dry samples were sieved with 0.125mm sieve and homogenized. This particle size range was chosen to facilitate comparison of heavy metal concentration with soil guidelines.

2.3. Sample Digestion and Analysis

1g of a well homogenized sample obtained from sample preparation procedure above was approximately weighed to the nearest 0.0001g into a Kjeldahl flask and 12ml of freshly prepared aqua regia (3ml HNO_3 + 9ml HCl i.e. ratio 1:3) was added. The beaker was covered and the contents heated for 2 hours on the medium heat of a hot plate until all bubbling had ceased. The mixture was allowed to cool and then filtered through a Whatman No. 42 filter paper into a 50ml standard volumetric flask. The filtrate was diluted to 50ml with de-ionized distilled water. Blank solutions were also prepared. The concentrations of lead, cadmium, iron, chromium and zinc in the solution were measured by Perkin Elmer 1100 atomic absorption spectrometer. All the samples were prepared and determined in duplicates and the data obtained were analysed using statistical tools. The digested samples were analysed in duplicates with the average concentration of the metal present being displayed in mg/L by the instrument after extrapolation from the standard curve and it was converted to mg/Kg

3. RISK ASSESSMENT

Risk assessment due to exposure to metal contamination in dust was carried out to estimate the non-cancer/cancer toxic (chronic) [8] and risk of workers (adults) and children exposed to the dust occupational hazards at the Westminister electronics market. Estimation of risk was calculated using

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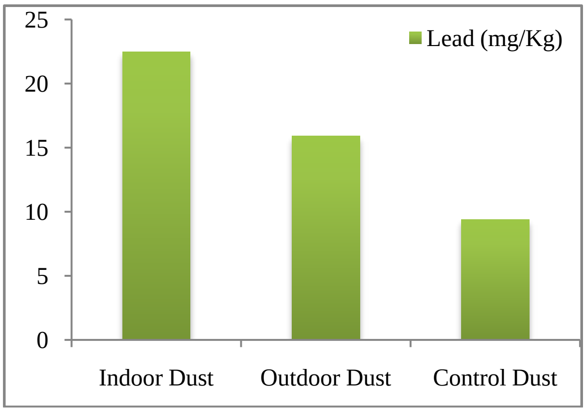
USEPA exposure factors handbook [22]. Average daily dose (ADD) of dust ingested was determined using the equation below.

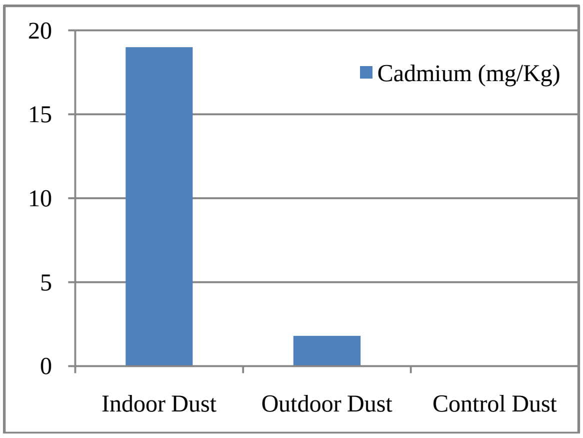
$$ADD = \frac{C \times IngR \times EF \times ED}{Bw \times AT}$$

C = mean heavy metal Concentration
IngR = dust ingestion rate (100mg/day for adults and 200mg/day for children)
EF = exposure frequency of 260 working days/year
ED = exposure duration of 6 years for children and 24 years for adults
Bw = Body weight of 60kg for adults and 15 kg for children was assumed
AT = Averaging time of 1300 days in 5 years.

4. RESULTS AND DISCUSSION



(a)



(b)

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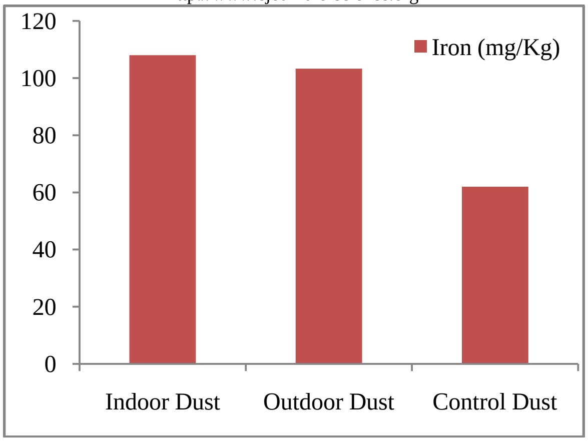

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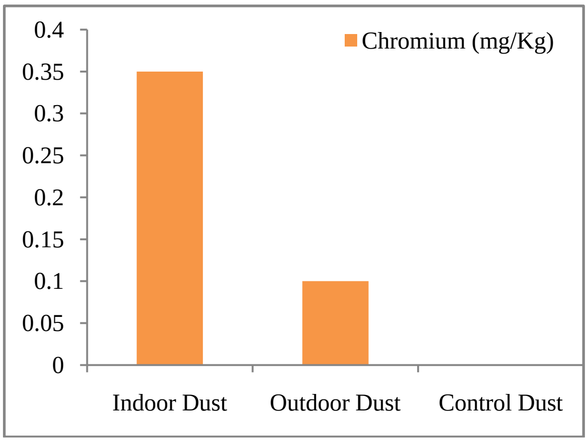

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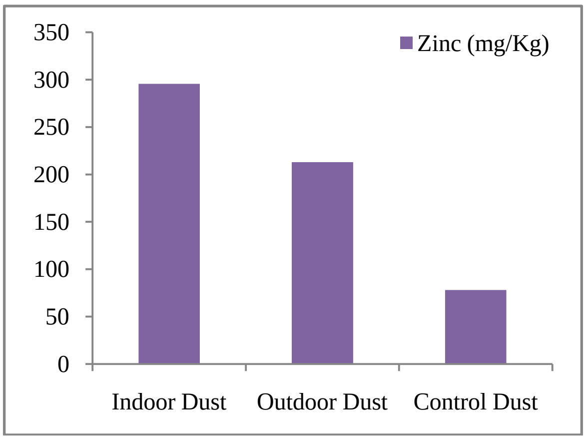

(e)

Figure 1. (a) – (e) shows the metal concentrations in the indoor dust, outdoor dust and control dust samples.

Figure 1(a) – (e) shows the metal concentrations in the indoor dust, outdoor dust and control dust samples. Table 2 shows the average daily dose of indoor dust ingested by adults and children and corresponding

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occupational hazard quotient. The mean heavy metal concentrations in indoor dusts were higher than the dust collected from the outdoor environment and control dust. Generally, concentrations of heavy metals in control dust were relatively lower than the indoor and outdoor samples. This difference showed that there were heavy metal pollution activities within the area. Currently, there are no guidelines or regulations for heavy metals in dust (Leung et al, 2006). To evaluate the extent of heavy metal contamination in the dust, the concentrations were compared to the New Dutch List Guidelines and the European Union Limits for these heavy metals in soils. Compared with other studies carried out in similar environmental media, the result of this study showed a relatively low contamination in general. This might be due to the fact that it is mainly the sale of UEEE and not its recycling that is carried out in the shops sampled at the Westminister Electronic Market. Notwithstanding, since toxicity is associated with continuous low level exposure, these reported mean heavy metals concentration can eventually lead to serious health effects.

The Lead concentration for the Indoor dust sample was 22.50mg/Kg, 15.90mg/Kg for the outdoor and 9.40mg/Kg for the control dust samples. The higher concentration of Lead in the indoor could be assumed to be as a result of contribution of e-waste to the overall Lead concentration in indoor dust. This is to say that there is interaction between e-waste and dust deposited on them over time. Mean Pb concentration for the samples were all below the New Dutch List optimum value (85mg/Kg) and EU limits (50-300mg/kg). Pb exerts toxic effects on various systems in the body such as the central (organic affective syndrome) and peripheral nervous systems (motor neuropathy), the hemopoietic system (anemia), the genitourinary system (capable of causing damage to all parts of the nephron) and the reproductive systems (male and female)(Harrington et al, 2003). The mean Cd concentrations of indoor dust (19mg/kg) were also found to be higher than the outdoor dust (1.8mg/kg) while none was detected in the control. The mean Cd concentrations in all the samples were found to be above the New Dutch List optimum value (0.8mg/Kg) and also its action value (12mg/kg) except for the outdoor dust. This is of concern because Cd is a potentially long-term cumulative poison. Toxic cadmium compounds accumulate in the human body, especially in the kidneys. There is evidence of the role of cadmium and beryllium in carcinogenicity (Pruss-Ustun, 2006).

The mean Fe concentration of indoor dust (108mg/Kg) was found to be higher than the outdoor dust (103.30mg/Kg) and control dust (62mg/Kg). The comparatively high amounts of Fe can be traced to its high presence in electronics. For example a typical desktop computer contains about 20.4712% of iron by weight of the total desktop weight. Chronic inhalation of excessive concentrations of iron oxide fumes or dusts may result in development of a benign pneumoconiosis, called siderosis, which is observable as an x-ray change (www.lenntech.com).

The mean Cr concentration of indoor dust was 0.35mg/Kg, 0.10mg/Kg for outdoor dust and none was detected in the control sample. The low concentrations of chromium in the samples might be due to its small amount in e-waste and also in nature. The health hazards associated with exposure to chromium are dependent on its oxidation state. It has been known to cause a lot of health problems like skin rashes, kidney and liver damage and also a possible carcinogen in humans (www.lenntech.com). The mean Zn concentration of indoor dust was 295.50mg/Kg, 213.0mg/Kg for outdoor dust and 78mg/Kg in the control dust. Zn concentrations in the samples were the highest compared to the other metals. The mean Zn concentration in the indoor and outdoor dust samples were above the New Dutch List optimum value (140.0mg/Kg) but were below its action value (720.0mg/Kg). The control sample had Zn concentration below the New Dutch List optimum and action values yet again confirming the interaction between heavy metals in e-waste and dust deposited on them over time. Zinc is an essential element in our diet. Too little zinc can cause health problems, but too much zinc is also harmful. Breathing large amounts of zinc (as dust or fumes) can cause a specific short-term disease called metal fume fever.

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5. RISK ASSESSMENT

The average daily dose of heavy metals ingested in dust per day in adults and children through the mouth (oral) and skin (dermal) route is calculated by using the IRIS (Integrated Risk Information systems) oral and dermal chronic reference doses in mg/day (USEPA) and heavy metal concentrations shown in figure 1. It has been established that HQ ≥ 1 is an indication of risk of cancer hazard. Oral hazard quotient (HQ 1.2) for zinc in adults indicates a risk of zinc toxicity as a result of large amount of zinc that could be ingested by adults. Dermal HQ results of 1.4 and 2.8 for cadmium recorded in adults and children respectively indicates a high risk of cancer, lung damage, high blood pressure and kidney damage. Children run a greater risk of cadmium toxicity because of its higher hazard quotient.

Table 2. Average daily dose of indoor dust injested by adults and children and corresponding occupational hazard quotient

Heavy Metals	**RD (oral) mg/day**	**RD (dermal) mg/day**	**ADD adults (mg/day)**	**ADD children (mg/day)**	**HQ adults (oral)**	**HQ children (oral)**	**HQ adults (dermal)**	**HQ children (dermal)**
Lead (mg/kg)	0.3	.	0.0002	0.0004	0.0067	0.013	.	.
Cadmium (mg/kg)	0.001	0.00001	0.000014	0.00028	0.014	0.0028	1.4	2.8
Chromium (mg/kg)	0.003	0.0075	0.000003	0.000006	0.001	0.002	0.004	0.008
Zinc (mg/kg)	0.002	0.054	0.0024	0.0048	1.2	0.0096	0.4	0.8

RD = IRIS reference dose absorbed both oral and dermal (through the skin)

ADD = average daily dose of heavy metals ingested from dust

HQ = hazard quotient

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6. CONCLUSIONS

The difference in the concentration of consecutive heavy metals in indoor and outdoor dust in this study supports the inference that: there is interaction between heavy metals within the components of e-waste and their surface dust, such as to contribute to the overall increase in metal concentration of the indoor dust. The mean Cd and Zn concentrations in the indoor and outdoor dust samples were found to be above the New Dutch List optimum value for these metals. Hazard quotient results also indicates that electronic dealers who store e-wastes and consumers who patronize the electronics market run a risk of zinc toxicity in adults and cadmium toxicity if this continues consecutively for a period of 5 years ingestion of dust either orally or dermally. Also, Children run a greater risk of consuming more dust per day and as such contact illness due to heavy metal toxicity.

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