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Assessment of Soil Contamination through E-Waste Recycling Activities in Tema Community One

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Abstract

The study investigated the level of heavy metal concentration in soils at e-waste recycling sites at Tema Community One. Two soil samples were collected from six different sites for laboratory analysis with a seventh location serving as a control. Heavy metals in soil samples were analyzed by digestion method and the use of atomic absorption spectrophotometer. The concentrations of Cadmium, Copper and Mercury were all higher at all the sites than those obtained for the control. The site that recorded higher concentration for copper was about 1200 times higher than the value for the control but statistically, there was significant difference between the concentrations of copper from the six sites ($t = 5.168$, $p = 0.0036$). Site 12 and Grand Mollen de Ghana site had concentrations which is 5 times higher than the control and there was significant difference between the concentrations from the six sites and the control ($t = 10.39$, $p = 0.0001$) for the cadmium. The mean concentration of mercury from site 12 was found to be 34 times higher than the control value, however, there was no significant difference between the concentrations from the six e-waste recovery sites and the control ($t = 2.593$, $p = 0.05194$). E-waste recycling has contributed to the heavy metal contamination of the soil at the recovery sites. Workers safety in relation to these heavy metals is therefore worth researching in the future.

Keywords: e-waste, recycling, heavy metals, contamination, soil

1. Introduction

Waste generation has increased drastically throughout the world and developing countries are not exempted due to high population growth, consumption of packaged products and adoption of Western life style through globalization and modernization. E-waste comprising electrical and electronic equipment (WEEE) and the quantities in waste generated by developing countries are gradually increasing (European Union, 2003a). The United Nations estimated that 20 to 50 million tons of e-waste are generated globally each year and Africa has been identified as one of the popular dumping grounds for old e-waste from the Western world (Koranteng & Darko, 2011). Ghana is not exempted from the problem of e-waste. In 2008, it was estimated that about 16,000 tons of e-waste was imported into the country (Koranteng & Darko, 2011).

The material constituent of e-waste in the waste stream has various substances which may be classified as hazardous and non-hazardous. According to Babu et al. (2007), about 66% of e-waste by weight consists of metals such as iron, copper, aluminium and gold and nonferrous metals such as copper, aluminium and other precious metals constitute about 13% by weight. They further noted that e-waste could contain more than 1000 different substances including lead (Pb), cadmium (Cd), mercury (Hg) and hexavalent chromium (Cr) which are mostly toxic (Babu et al., 2007; Gaulon et al., 2005). Also it has been estimated that 21% by weight of e-waste represent plastic materials in Europe (Wilkinson et al., 2001; ETC/RWM, 2003). Glass component forms about 5.4% of the total weight of waste from electric and electronic equipment every year in Europe (Theisen, 2002).

In this study, e-waste recycling means breaking down obsolete electronic materials to recover valuable materials which can be reused in another device or processed into a new product. This can actually help recover reusable components and base materials, such as Cu and other precious metals. However, inadequate facilities, high labour costs, and stringent environmental regulations have contributed to advanced countries not motivated to recycle e-waste but land filling, or exporting them to developing countries which is against the objectives of the Basel Convention (UNEP, 2009). In developing countries, primitive techniques are used in recycling, which may affect workers safety, public health and the environmental (Cobbing, 2008).

Studies have shown that e-waste can leach polychlorinated biphenyl's (PCBs) which are bioaccumulative in organisms and can lead to biomagnifications through the food chains and cause endocrine disruption (Deng et al., 2007). Heavy metals found in e-waste such as Cd, Hg and Cu are known to be persistent in the environment, accumulative in plants, animals, humans and the environment. Exposure to these metals and their compounds are known to cause problems to the nervous system and genitourinary system (CDPHE, 2008; Tangahu et al., 2011; ATSDR, 1999; WHO, 1992). Land filling of obsolete refrigerators, freezers and air conditioning units containing ozone-depleting gases such as chlorofluorocarbons (CFCs) can release the gases which can have adverse environmental effects (Scheutz et al., 2004). Studies conducted on sediments taken from certain rivers in Guiyu, China were contaminated with high levels of Cd, Cu, Ni, Pb, and Zn (Wong et al., 2007; Herat, 2009).

E-waste generation rate is estimated to be less than 1% of municipal waste generated in Accra (WMD of AMA, 2010). In Ghana, there are many centres for recovery of valuable materials from e-waste but the main centre for this recovery activity within the country is the Agbogbloshie Scrap Market in Accra. Studies have been done on soil contamination through e-waste recovery at Agbogbloshie and Koforidua (Brigden et al., 2008). The present study sought to assess the potential of e-waste recycling activities to contribute to heavy metals contamination of the soils in Tema, Ghana.

2. Methodology

2.1 Description of Study Area

Tema as the industrial hub of the country is the third urbanized city in Ghana after Accra and Kumasi, hosting the country's biggest harbour. Geographically, it is located on (5°37′0′′N, 0°10′0′′W). The city is bounded to the North-East by Kpong Katamanso District Assembly, to the South-West by Ledzokuku-Krowor Municipality, to the North-West by Ashaiman Municipality and to the south by Gulf of Guinea. It has an estimated population of 402,637 with males and females forming 48% and 52% respectively (Ghana Statistical Service, 2012). E-waste scraps dealers activities are doted around the city especially in Community One which is located in Tema West.

2.2 Soil Sampling and Preparation

Soil samples were taken from e-waste recovery sites at Tema Community One. In all, a total of 12 composite soil samples were taken from six e-waste recycling sites to provide duplicate samples and two were taken from the same community but outside the e-waste recycling sites. The soils were taken at a depth of 30cm from the surface of the ground using augur and kept in polyethylene bags in ice pack, sealed, labeled and transported to the Soil Research Institute (CSIR) laboratory for analysis. The soil samples were emptied into trays labeled according to the sample sites. The soil sample were freed from foreign objects (roots, pebbles, etc.) and later air dried. The samples were crushed, ground and homogenized using a porcelain pestle and mortar and were then passed through 2.0 mm sieve pore to constitute the actual workable samples. The workable soil samples were then placed into their respective labeled polyethylene bags and stored at room temperature, for the next phase of the analytical process.

2.3 Laboratory Analysis

The total Cd and Hg and Zn concentrations were determined using the US-EPA method 3050 of digestion of soil for metal content. A 0.5 g portion of soil was weighed into a beaker followed by addition of 10.0 ml of 1:1 HNO_3: H_2O to form a solution. The solution was heated to 95 °C for 5 min, followed by sequential addition of 5.0 ml of concentrated HNO_3, 1.0 ml of 30% H_2O_2, and 5.0 ml of concentrated HCl. The resulting solution was filtered and diluted with deionised water to a final volume of 50.0 ml. The filtrate was kept in spinning tubes for analysis using Atomic Absorption Spectrophotometer (Fan et al., 2011).

2.4 Data Analysis

Data from the laboratory results were tested for significant difference using computer application software called Palaeonotological Statistical Tool (PAST), at 95% confidence level for one tailed t-test. The means were generated from the spread sheet 2007 version of Microsoft.

3. Results and Discussion

Table 1. Mean concentrations of heavy metals from e-waste recycling sites in Tema Community 1

Heavy Metal /Location	GMG	Site 20	Site 2	Site 12	Harbour Area 1	Harbour Area 2	Control	Instrument Detection Limit
Copper (mg/kg)	7834.92	1688.11	5686.72	5047.06	4003.46	3006.92	6.50	0.003
Cadmium (mg/kg)	2.60	1.80	2.40	1.60	1.95	1.40	0.50	0.002
Mercury (mg/kg)	0.94	0.12	0.50	1.30	0.13	0.11	0.04	0.001

Source: Field soil sample analysis Data, 2012 at Soil Research Institute–Accra.

Table 2. Mean ratios of metal levels in the soils at the sites in relation to the sampled control

Heavy Metals/E-waste Recovery Site	GMG	Site 20	Site 2	Site 12	Harbour Area 1	Harbour Area 2
Copper	1200	259	871	773	613	460
Cadmium	5	4	5	3	4	3
Mercury	25	3	13	34	3	3

Table 1 above revealed that the concentrations of Cu, Cd, and Hg were very high as compared to the control taken from the same vicinity where there was no e-waste recycling activity going on.

3.1 Copper

It was found out that GMG site had the highest Cu concentrations followed by Site 2 and Site 12. Thus, the mean concentration of Cu at the GMG site was about 259–1,200 times higher than that of the control as shown in table 2. Statistically, there was a significant difference between the concentrations from the six sites ($t = 5.168$, $p = 0.0036$). This implies that recovery of valuables from e-waste using the crude methods can contribute copper to the soil in high levels leading to contamination. These values are high compared with similar studies conducted at Agbogbloshie (9,730 mg/kg) and Koforidua (14,300 mg/kg) in Ghana (Brigden et al., 2008). Even though Cu is one of the valuable materials from e-waste, it is also known to serve as a catalyst for dioxin formation if the recycling activities are done using crude methods like open burning (Cui & Zhang, 2008). Copper can affect water bodies, soil fertility, reduce microbial activities and crop production (Fan et al., 2011). It has been established that chronic exposure to Cu can lead to liver and kidney disorders with vomiting and abdominal pains as the symptoms (New Hampshire Department of Environmental Services, 2005). Exposure to high levels of Cu through inhalation is known to cause irritation of nose and throat, ingesting can cause nausea, vomiting, diarrhea, damage to the liver and kidneys, and can even cause death under extremely high ingestion (CDPHE, 2008).

3.2 Cadmium

Cadmium was the lowest in concentration after mercury at all the sites with the highest concentration occurring at GMG Site, followed by Site 2 and Harbour Area 1 respectively as indicated in Table 1. Thus, the mean concentration of Cd was about 3-5 times higher than that of the control. These values however were very low compared to values obtained for Cd from other extraction or recycling sites at Agbogbloshie (10 mg/kg) and Koforidua (3 mg/kg) sites (Brigden et al., 2008). This means that the recycling activities could contribute to the contamination of the soil which could pose life risk to the recyclers or value pickers working at these sites. Normally cadmium levels below 2 mg/kg in soils and sediments are taken to be acceptable (Brigden et al., 2008; Alloway, 1990; Salomons & Forstner, 1984). In this study, GMG Site and Site 12 had a mean value of 2.6 mg/kg and 2.4 mg/kg respectively and were higher than the control values and can be said to be contaminated. Statistically, there was a significant difference between the concentrations from the six sites ($t = 10.39$, $p = 0.0001$). Cadmium is known to affect the kidney and its compounds are known to cause lung cancer in humans through inhalation (DHHS, 2005). Therefore the workers at these site and inhabitants in the area may be at risk of contract some of these diseases once exposed to the metal.

3.3 Mercury

Mercury which causes a lot of hazards in environmental media and in humans was also detected at the e-waste recovery sites. The mean concentration of Hg from the Site 12 was found to be the highest, followed by GMG and site 2 respectively. Thus, Hg mean concentration was found to be about 3–34 times higher than that of the control. These values indicated that the e-waste recovery sites were contaminated with mercury and this could affect the health of workers at these sites and neighboring households who may be exposed to it. Statistically, there was no significant difference between the concentrations from all the six e-waste recovery sites ($t = 2.593$, $p = 0.05194$). Mercury and its compounds are known to be toxic and accumulative, causing neurological and renal disturbances in humans (Tangahu et al., 2011). Mercury as a metal is known to affect the genitourinary system, the central and peripheral nervous systems as well as foetus. Inorganic mercury can leach or wash by runoffs into water bodies and can be transformed into methylated mercury, which bioaccumulates in living organisms and concentrates through the food chain, especially by fish (Pinto, 2008). Even though mercury concentrations were not significant in the soils, it could accumulate in the environment and pose serious risk to organisms and humans within the Community One environment.

4. Conclusion

The result of the study showed that Cd and Cu were present in the soils where e-waste recycling activities were carried out at appreciable levels whilst Hg was not significant. Thus, e-waste recycling activities at these sites were contributing to heavy metals pollution to the soil. The concentrations of the Cd, Hg, and Cu determined were in excess compared to the concentrations of the same metals in the control. Therefore the hypothesis that the concentrations of Cd and Cu in soils at e-waste recovery sites were higher than the soil without recycling activities was accepted and was rejected for Hg. It is therefore important to investigate for the presences of other heavy metals, substituted organic compounds and their health implications on the scrap dealers at the sites.

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