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ASSESSMENT OF THE CONCENTRATION OF HEAVY METALS IN ELECTRONIC WASTE DUMP SITE IN ALABA INTERNATIONAL MARKET, LAGOS STATE

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ABSTRACT

This research investigates the concentration of heavy metals (Pb, Cu, Cd, and Ni) at e-waste dump sites in Lagos, Nigeria. Measuring the concentration and distribution of heavy metals across different soil depths and comparing these concentrations in soil and water samples. For this purpose, 78 soil samples were taken from different sampling points, and analyses were carried out following standard procedures. The soil samples retrieved from the e-waste site consistently exhibit a sandy soil texture, as per the USDA classification system. It was found that Cu generally has the highest concentrations in the soil layers (2022.20-2312.67mgkg^{-1}**)** while Cd generally has the least (16.32-22.62 mgkg^{-1}**).** The elements observed for this study are Cu > Pd >Ni > Cd. Overall, this comprehensive study provides valuable insights into the environmental contamination and health risks posed by e-waste dump sites, emphasizing the need for effective management strategies to mitigate these risks and protect human health and the environment.

Keywords: Soil contamination, Pollution, Heavy metals, Electronic waste, Alaba International Lagos, Nigeria

INTRODUCTION

The escalating accumulation of electronic waste (e-waste) has emerged as a pressing environmental and public health concern in the 21st century (Chen et al., 2011). E-waste, encompassing discarded electrical and electronic equipment, including household appliances and consumer electronics, poses significant threats to human health and the environment, particularly in developing countries with inadequate municipal waste management systems. Defined as obsolete, unserviceable, or end-of-life electronic devices, e-waste is also referred to as e-scrap or Waste Electrical Electronic Equipment (WEEE) (Benebo, 2014). The rapid growth of Information and Communication Technology (ICT) has fueled the demand for Electrical Electronic Equipment (EEE), resulting in the alarming accumulation of e-waste. Notably, over 30 million computers are discarded annually in the United States, and over 100 million phones are disposed of in Europe each year, highlighting the urgency of addressing this environmental issue (Benebo, 2011).

The rapid proliferation of electronic devices, including personal computers, mobile phones, and entertainment electronics, has catapulted electronic waste (e-waste) as the fastest-growing component of municipal solid waste. Concurrently, the massive exportation of Electrical and Electronic Equipment (EEE), comprising Used Electrical Electronic Equipment (UEEE), from developed nations to developing countries in Asia and Africa has become a pressing concern. This phenomenon is driven by the desire to bridge the digital divide, with millions of tons of EEE being shipped annually (Benebo, 2011). However, research reveals that a significant proportion of imported second-hand EEE is, in fact, waste electrical and electronic equipment (WEEE), with studies indicating that less than 25% of imported consignments are functional UEEE, while over 75% are non-functional WEEE (Benebo, 2011). A case in point is Nigeria, where approximately 25-75% of imported second-hand computers in 2005 were found to be non-functional and beyond repair (Ogungbuyi et al., 2012). This alarming trend has resulted in an unprecedented influx of near-end-of-life and end-of-life electrical and electronic appliances, ultimately contributing to the burgeoning e-waste problem in developing countries.

The escalating electronic waste (e-waste) problem is not limited to developed nations, as developing countries also generate substantial quantities within their territories. Globally, an estimated 20-50 million tons of electronic scrap are generated annually, with 75-80% being exported to Asia and Africa for recycling and disposal (Jack et al., 2011). In Nigeria, for instance, e-waste primarily originates from imported second-hand electronics, which are crudely recycled by informal scavengers, releasing hazardous substances into the environment (Popoola et al., 2013). Despite containing recoverable materials, Waste Electronic and Electrical Equipment (WEEE) poses significant environmental and health risks due to its toxic and hazardous constituents (Ogbomo et al., 2012). The environmental implications of e-waste are far-reaching, contaminating surface and groundwater, air, and soil, and affecting entire ecosystems (Terada, 2012). A primary driver of the e-waste crisis is the brief lifespan of electronic devices, typically less than two years for computers and cell phones (Bhutta et al., 2011). The proliferation of new high-technology electronic products has led to an explosion in e-waste generation. Electronic devices comprise a complex array of chemical elements and compounds, with some containing up to 1000 different substances, including metals (Ohajinwa et al., 2018).

Another group of e-waste toxicants that are of serious concern to environmentalists is heavy metals.

Heavy metals, a subset of elements exhibiting metallic properties, comprise transition metals, metalloids, lanthanides, and actinides, pose significant environmental concerns due to their toxicity and ecotoxicity (Duffus, 2002). These metals can be categorized into essential and non-essential groups based on their biological roles. Essential heavy metals, such as iron (Fe), copper (Cu), zinc (Zn), and manganese (Mn), are vital for living organisms, playing crucial roles in biochemical reactions and physiological processes, albeit in minute quantities (Hazrat et al., 2019). Conversely, non-essential heavy metals, including cadmium (Cd), lead (Pb), and mercury (Hg), lack biological functionality and are toxic, posing substantial environmental and health risks.

Soil contamination by heavy metals, particularly those associated with electronic waste (e-waste), such as mercury (Hg), beryllium (Be), cadmium (Cd), lead (Pb), and chromium (Cr), poses a persistent and formidable environmental challenge. Unlike air or water pollution, heavy metals in soil can persist indefinitely, with certain metals like lead and chromium potentially remaining permanently (Okeyode and Moshood, 2010). Soil contamination, defined as the degradation of biophysical and biochemical properties due to anthropogenic or natural factors, can irreversibly alter soil physicochemical properties, rendering it unsuitable for agricultural purposes (Abdu et al., 2011). Moreover, contaminants in soil can be readily absorbed by plants, which, when consumed by humans, pose significant health risks and hazards.

MATERIALS AND METHODS

Alaba International Market is located in Lagos State, Nigeria, (latitude 6°27'58.25952"N, longitude 3°11'36.60366"E) which is widely acknowledged as the largest city in Nigeria and one of the fastest-growing cities globally. Lagos plays a crucial role in trade and commerce, not only within Nigeria but also across the entire West African region. The city is home to two major seaports, namely the Lagos Port Complex and the Tin Can Island Port, serving as pivotal trade gateways for the import and export of goods not only for Nigeria but also for neighboring West African countries. The city is in a flat, coastal area characterized by dense forests, swamps, marshes, and lagoons. With a population of approximately 17.5 million people, Lagos experiences a tropical climate with moderate temperatures, relative humidity, and a notable low water table. This low water table is significant as it implies that hazardous waste can easily leach and contaminate the groundwater.

Alaba International Market holds the distinction of being the largest electronics market in West Africa. Established in 1978, the market spans an area of about 2 km² in the southwestern part of Lagos. Featuring over 2500 shops engaged in refurbishing and offering used electrical and electronic products for sale, it has become a prominent hub in the region (Oladapo *et al*., 2012).

Study Site

The area where these activities take place spans approximately 4500 square meters. Site workers further divided the site into two sections: one designated for dismantling and the other utilized for burning to recover materials. A specific starting point was chosen, and a systematic square grid sampling strategy was implemented. The entire area was subdivided into equal sub-areas, and sampling locations were determined at intervals of 20 meters. Around 25 points were sampled in the recycling section, with soil samples collected at each point to a depth of up to 45 cm in the ground. In the dismantling section, soil samples were randomly collected, as attempting to dig the soil provoked objections from the site workers.

Soil Sampling

Soil samples were obtained from e-waste recycling and dumpsites, involving 15 auger points collected at three different depths (0-15 cm, 15-30 cm, and 30-45 cm). Each depth yielded 25 samples, with three additional samples taken as controls, resulting in a total of 75 samples. Water samples were also collected from a well near the waste site and from the control site, maintaining a 20-meter distance. The soil samples underwent air-drying, thorough homogenization, crushing with a porcelain pestle and mortar, and sieving through a 2mm mesh for heavy metal analysis were carried out at the Soil Science Department, IAR, ABU, Zaria.

Determination of Heavy Metals

This was determined after digestion with aqua regia (HNO_3, HF, and HCl) (Lim and Jackson, 1986). 0.2 grams of air-dried and finely ground soil was weighed into a Teflon beaker and digested with a 2:3:2 mixture of HNO_3, HF, and HCl at 80°C. The beaker was swirled gently and digested on a digestion block until brown fumes appeared which subsequently turned white indicating full digestion. The digested soil samples were set aside to cool and filtered through the Whatman No. 42 filter paper and diluted to 50 ml with distilled water in clean plastic vials before analysis. The concentration of Cu, Cd, Pd, and Ni in the digest was determined with an Atomic Absorption Spectrophotometer (AAS: Model AA 6680, Shimadzu, Kyoto, Japan. The concentration of heavy metals was compared with a standard.

Data Analysis

All statistical analyses were conducted using R Statistics for Windows v.4.0.3. Analysis of variance (ANOVA) was carried out to compare the difference of means from various sampling sites, followed by multiple comparisons using the Duncan Multiple Range Test (DMRT) to separate the means.

RESULTS AND DISCUSSION

The concentration of heavy metals showed wide variations. There were significant differences in all the samples. The lowest concentration of Cadmium (0.00 $mgkg^{-1}$) was recorded for control, while the highest concentration of 22.62 $mgkg^{-1}$ was recorded at 15-30cm. These values are extremely higher than the 3.0 $mgkg^{-1}$ acceptable Cd concentrations in arable lands. (Table 1). Copper concentration showed very wide variation. The values ranged from 58.42 $mgkg^{-1}$ to 2312.67$mgkg^{-1}$ in Control a15-30cm respectively. These values are very high when compared with standard thresholds for arable soils. Although the highest Pb concentration (812.60 $mgkg^{-1}$) was recorded at 0-15cm, the lowest concentration of 96.17 $mgkg^{-1}$ was recorded for control. Surprisingly, Ni had the highest concentration of 881.66 $mgkg^{-1}$ at 30-45 while the lowest concentration of 6.83 $mgkg^{-1}$ was recorded at 30-45 (Table 2)

The elevated concentrations of total metals (Cd, Cu, Pb, and Ni) in the dumpsite soil raise significant environmental concerns, with Cd levels exceeding permissible limits for arable lands. The wide variations observed in metal concentrations, especially the elevated levels of Cu and Pb, underscore the severity of contamination in soil dumpsites. Cadmium levels, for instance, exceeded acceptable concentrations for arable lands, presenting a potential threat to ecosystems and agricultural productivity. Similarly, the significant variation in Copper concentrations, reaching extremely high values, highlights the severity of the contamination issue, surpassing established thresholds for arable soils. This aligns with findings in global studies, such as research in China revealing heavy metal contamination in e-waste-affected soils (Li *et al.*, 2019). The high Cu concentration in all the sampling stations indicates high copper concentration in the electrical composition.

Table 1: Soil classification down depths of the soil at e-waste dump site

SOIL	CONTROL	0-15	15-30	30-45	p value
(%) Clay	4.00±0.01	4.00±0.01	4.00±0.01	4.00±0.01	0.003
(%) Silt	$0.67±0.00^{b}$	$2.56±0.00^{a}$	$2.88±0.00^{a}$	$2.88±0.00^{a}$	0.043
(%) Sand	95.33±0.67	93.44±.0.59	93.12±0.66	93.12±0.57	0.661

Mean±SE with different superscripts across the row are significantly different $p<0.05$

Table 2: Mean concentration of metals down different depths of the soil of the e-waste dumpsite

Metals	CONTROL	S0-15	S15-30	S30-45	p value
Cd	$0.00±0.00^{c}$	$16.32±1.49^{b}$	$17.35±1.90^{b}$	$22.62±7.24^{a}$	0.035
Cu	$58.42±30.96^{b}$	$2231.18±172.57^{a}$	$2312.67±164.80^{a}$	$2022.20±191.80^{a}$	0.001
Pb	$96.17±31.37^{c}$	$812.60±59.72^{a}$	$801.36±65.28^{a}$	$754.97±80.08^{a}$	0.009
Ni	$6.83±6.83^{b}$	$786.41±150.16^{b}$	$795.83±138.95^{a}$	$881.66±156.52^{a}$	0.029

Mean±SE with different superscripts (a-c) across the row are significantly different $p<0.05$
Key: S0-15 = Soil at depth 0-15cm, S15-30 = Soil at depth 15-30cm, Soil at depth 30-45cm

The value was still higher than the values Abdu (2010) reported in wastewater-irrigated vegetable garden soils in Kano, Nigeria, and some of the values reported by Adelekan *et al.* (2011) in soil and groundwater. It was found that Cu generally has the highest concentrations in the soil layers, while Cd generally has the least. The elements observed for this study are Cu > Pd > Ni > Cd.

Table 3: International threshold values for heavy metals concentration in soils (mgkg^{-1})

Heavy Metal	UK	Regulatory System		
		EU	USA	Canada
Cd	1.4	3.0	3.0	19.5
Zn	200	300	200-300	1400
Cr	6.4	180	400	1500
Cu	63	140	80-200	170
Pb	70	300	300	150
Ni	50	75	50-110	210

Source: CCME (2001).

Metal pollution has harmful effects on biological systems and does not undergo biodegradation. Toxic heavy metals such as Cu, Ni, Pb, and Cd can be differentiated from other pollutants since they cannot be biodegraded but can be accumulated in living organisms, thus causing various diseases and disorders even in relatively lower concentrations. However, the contaminated soil samples showed a high level of metal contamination due to recycling and dismantling activities. The abundance of metals was consistently in this order: Cu > Pb > Ni > Cd. High Cu and Ni concentration in the control suggests that the major sources may be anthropogenic activities. Cadmium levels may lead to elevated concentrations, which may eventually leach to the groundwater, resulting in negative consequences for human health. When compared to control samples, High Pb, Cd, and Cu were found in soil e-waste areas. However, it was found that Cu generally has the highest concentrations in the soil layers while Cd generally has the least.

CONCLUSION

The values of Cd obtained from this study still were far above the permissible level for soils in most countries. This raises significant environmental concerns and calls for urgent attention and appropriate response. This level of Cd content in the effluent is toxic and requires proper treatment before disposal on land as it is not safe for final release which is also harmful to man and other living organisms and can also deteriorate soil quality as well as fertility. Public awareness campaigns can play a crucial role in educating the community about the environmental and health hazards associated with improper e-waste disposal and hence should be adopted. In addition, there is urgent need for proper treatment and regulatory intervention to prevent harm to both human health and the environment.

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