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Ecological and Human Health Risk Assessment of Heavy Metals Contamination of Soil in E-Waste Dumpsite in Atan, Ogun State, Nigeria

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ABSTRACT: *Environmental problem tends to be growing globally especially in developing countries due to the advancement in technology via indiscriminate disposal of electronic wastes, this has continued to pose serious threat to human health. The present study aimed at determining the level of heavy metals in e-waste dumpsite and evaluates the ecological and human health risk of soil contaminated with heavy metals in Atan e-waste dumpsite. The results of the analysis revealed that the concentrations of Cd ranged from 64.20 to 207.99 mg/kg, Cr; 414.83 to 470.47 mg/kg, Pb; 1036.89 to7362.36 mg/kg, Cu; 2963.8 to 3993.78 mg/kg, As from 149.12 to 250.03 mg/kg, and Zn; 21034.74 to 25119.61 mg/kg. The mean concentrations occurred in the order of; Zn > Pb > Cu > Cr > As > Cd. Zn had the highest concentration of 2098.45 mg/kg while Cd had the lowest concentration, 64.20 mg/kg. The values of all the metals determined in the soil were higher than the control and the tolerable limits recommended by World Health Organization. The ecological risk index of all the metals in the e-wastes soil indicated a high risk. Hence, heavy metals in soil around e-wastes dumpsite in Atan, Ogun State present serious health risk whilst urgent measures are required.*

KEYWORDS: Contamination, Dumpsite, E-waste, Ecological, Heavy Metals, Soil

INTRODUCTION

Technology has advanced rapidly since the turn of the twentieth century, particularly in the field of electronics. As a result of the rapid expansion of electronic technology, it has steered the continuous advancement of electronic items, and the indiscriminate disposal of these products has resulted in a vast stream of municipal solid garbage around the world. (Ouabo, Ogundiran, Sangodoyin, & Babalola, 2019). Electronic trash, or "e-waste," is defined as any abandoned, outmoded, or damaged electrical or electronic item (Sankhla, Kumari, Nandan, Kumar, & Agrawal, 2016). Examples of e-waste sources include computers, monitors, motherboard/chips, wireless devices and other peripheral items, printers, copters, fax machines, telephones, mobile phones, video cameras, televisions, stereo equipment, cathode ray tubes, cables, lamps, large household appliances among others. Globally, e-waste is expanding at over three times the rate of municipal solid garbage, according to current estimates (CEA, 2010). E-waste is considered as an emerging environmental problem, the reason being that it is composed of a

heterogeneous mix of different metals, metalloids, plastics and glass. Because there is no effective elimination mechanism for heavy metals, they are classified as hazardous chemicals to the body even at low concentrations (Chen, Wu, Shao & Ying, 2014).

Heavy metals are any metallic chemical element that have a relatively high density and are toxic or poisonous at low concentration examples are cadmium, chromium, lead, arsenic, copper, zinc etc. They are naturally occurring components that cannot be degraded and are dangerous because they increase in concentration of biological organisms Olafisoye, Adefioye, & Osibote (2013). Heavy metals from e-waste accumulates the soil as a contaminant which leads to uptake of heavy organic matter, clay contents and pH and also influences the biological and biochemical properties (Matin, Kargar & Buyukisik, 2016). As a result of both natural and manmade activities, such as indiscriminate disposal of e-waste, heavy metals tend to contaminate and degrade soil. Waste disposal at dumpsite have been described as one of the major contributors of heavy metals pollution in the environment. The majority of Nigeria's dumpsites are now located in residential areas, exposing residents to harmful pollution. The soil is the primary sink for heavy metals discharged into the ecosystem as a result of anthropogenic activities such as indiscriminate electronic trash dumping, car exhaust, and so on. Heavy metals do not degrade microbially or chemically at high or low concentrations, therefore they persist for a long time after their introduction (Wuana & Okieimen, 2011). These activities pollute the soil by poisoning the ecosystem's food chain. Adults inhale roughly 100 mg of dust each day, according to studies, and children are exposed to more soil dust than adults due to their play behavior. (Ouabo et al., 2019). The main route by which humans are exposed to heavy metals which are; inhalation, ingestion and dermal contact, have become toxic to human because they cannot be metabolized by the body (Singh & Kalamdhad, 2011), thus, this leads to harmful effect of the body thereby causing cancer, kidney damage, brain disorder, blood emphysema, hepatic destruction, damage of testicular tissue and red blood cell and may also lead to death (Kyere, Greve, Atiemo, Amoako, Aboh & Cheabu, 2018).

The objectives of the present study were to examine the levels of heavy metals in soil from e-waste dumpsite in Atan, Ogun State, Nigeria and to evaluate the potential ecological and health risk concerns to adults and children around the vicinity.

METHODOLOGY

Study area

The study area was an electronic waste dumpsite in Atan, Ogun State, Nigeria. Atan is a frontline town located in the Ado-Odo/Ota Local Government Area. It is one of the 19 Local Government Areas of Ogun State in Southwest Nigeria. It is situated at 6°46'0"N 2°47'60"E and is 575 kilometers (357 M) West of Abuja and 62 km (39 M) Northeast of Cotonou. The town is brimming with over 300,000 residents and it is a hub of business activities. Atan is bounded by the Lagos State Local Governments of Ojo and Badagry in the South and Alimosho in the East. Yewa South and Ifo Local Governments in the North and Ipokia Local Government. It lies right on the international route linking Nigeria with the Republic of Benin and directly West of Sango Ota Township. Most of the residents are traders who sell foodstuffs, agricultural produce, electronic appliances, clothing's, woods etc.

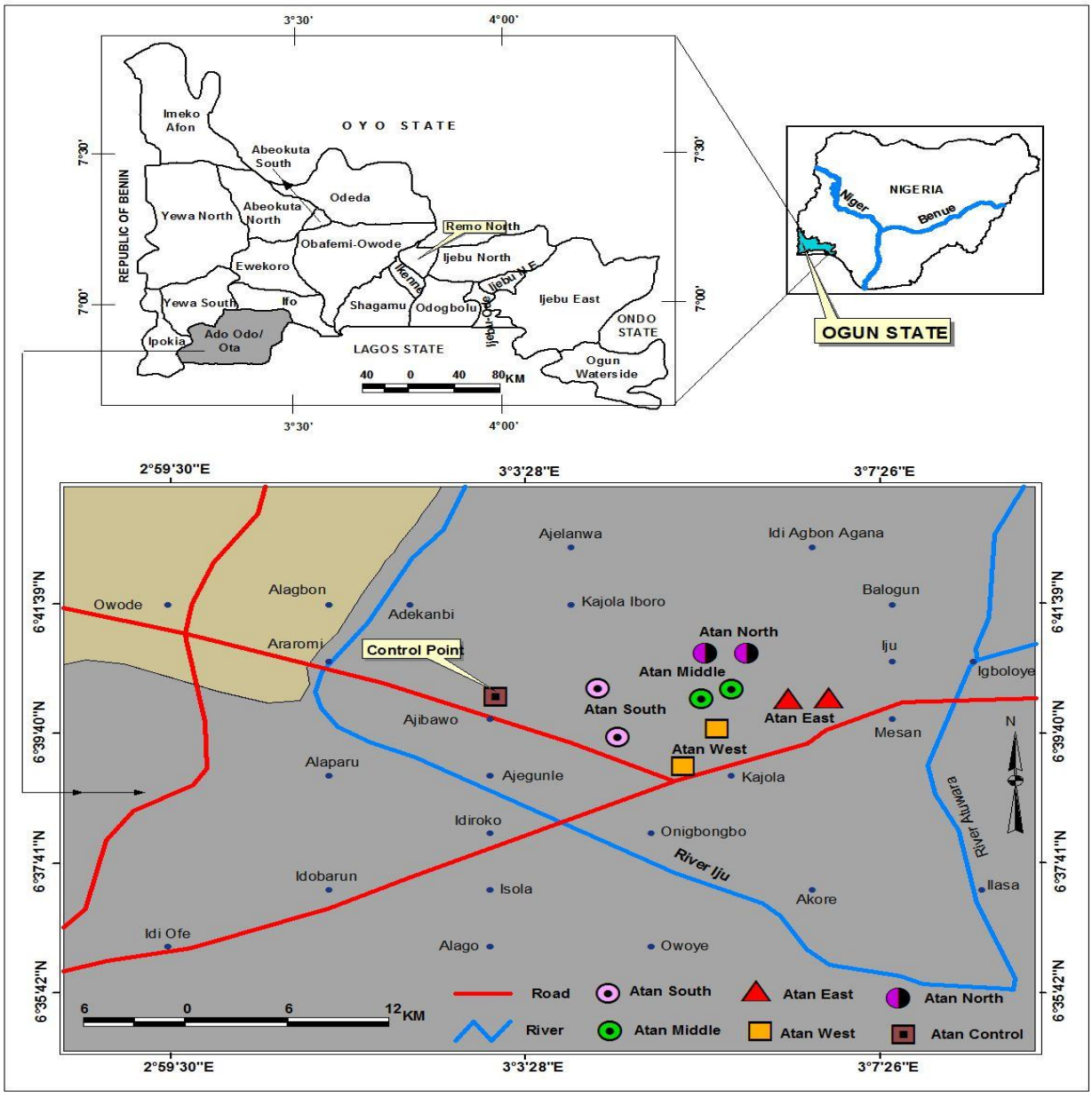

Figure 1: Map of sample location in Atan, Ogun State Nigeria

Sample Collection and Preparation

A total of nine (9) soil samples were collected at 0-15 cm depth at the exact sampling points using a stainless-steel auger and designated distance of 100 m along the four cardinal points; North, South, East, West and Centre of the dumpsite. The control sample was collected at about 500 meters away from the dumpsite. At each sampling sites, composite samples were collected in a clean polyethylene bag, well

labelled, stored in ice-filled coolers and transported to the laboratory. The soils were air-dried for 12days, ground and sieved through a 2 mm sieve.

Acid Digestion

The samples were digested using aqua regia method according to the United State Environmental Protection Agency (USEPA, 3050B). 1 g of the dried sample was weighed; each sample was transferred into a beaker containing a mixture of 4 mL of 50 % nitric acid (HNO_3) and 10 mL of 20% hydrochloric acid (HCl). Digestion was carried out on a hot plate in a fume hood with the temperature not exceeding 90^{o}C for about an hour. At the end of the digestion, digestate was filtered and diluted to 50 mL using ultra-pure deionized water.

Heavy Metal Analysis

The heavy metals concentration in the samples was determined using Inductively Coupled Plasma Optical Emission Spectrophotometer (ICP-OES) Agilent 720 ICP-OES. The heavy metals analysed in this study were; lead (Pb), chromium (Cr), cadmium (Cd), copper (Cu), arsenic (As), and zinc (Zn).

Ecological Risk Assessment

Pollution indices are useful tools in processing, analyzing and conveying raw environmental information to the people (public and decision makers) (Caeiro et al., 2005). The pollution indices used to evaluate the level of heavy metals contamination in the E-dumpsite in this study are, geo-accumulation index (Igeo), contamination factor (Cf), pollution load index (PLI), and enrichment factor (Ef).

Geo-accumulation Index (Igeo)

This parameter is considered to assess pollution by heavy metals in surface soil samples. The geo-accumulation index (Igeo) of each metal was calculated as indicated in Eq. 1 as applied by Uzoekwe & Richard (2020).

$$Igeo = Log_2(\frac{C_s}{I.5B_n}) \quad (1)$$

Where; Cs is the measured concentration of metal in sample, Bn is the background concentration of the metal which in this study was taken as the concentration of the respective metals in the control sample, factor 1.5 is used because of possible variations of the background data due to lithological variations.

The resultant values were classified as Igeo ≤ 0 (uncontaminated), 0 <Igeo< 3 (moderately to heavily contaminated), 3 <Igeo< 4 (heavily contaminated), 4 <Igeo< 5 (heavily to extremely contaminated), Igeo ≥ 5 (extremely contaminated), based on the application by Uzoekwe & Richard (2020).

Contamination Factor (Cf) and Degree of Contamination (Cd)

Contamination factor is a quantification of degree of contamination relative to either average composition of respective metal or to the measured background from similar uncontaminated area. The contamination factor (CF) was calculated as indicated in Eq. 2 (Ngole-Jeme, 2015).

$$CF = \frac{C_m}{B_m} \quad (2)$$

Where; C_m is the measured concentration of heavy metal in the soil and B_m is background concentration of the metal.

The obtained values were classified based on the following criteria viz: CF < 1 (low contamination); 1 ≤ CF < 3 (moderate contamination); 3 ≤ CF < 6 (considerable contamination); CF ≥ 6 (very high contamination) for contamination factor and CD < 8 (low risk); 8 ≤ CD < 16 (moderate risk); 16 ≤ CD < 32 (considerable risk); CD > 32 (very high risk) for degree of contamination. Pollution load index was calculated based on the method previously described by Tomlinson, Wilson, Harris, Jeffrey (1980) and have been applied by Uzoekwe & Richard (2020). The result values were ranked as PLI < 1 (no pollution); 1 < PLI < 2 (moderate pollution); 2 < PLI < 3 (heavy pollution); 3 < PLI (extremely heavy pollution).

Pollution Load Index (PLI)

Pollution load index provides information about toxicity of metals in the studied samples. The pollution load index (PLI) was calculated using the formular indicated in Eq. 3 (Ngole-Jeme, 2015).

$$PLI = n\sqrt{CF_{Cd}\ x\ CF_{Cr}\ x\ CF_{Pb}\ x\ CF_{Cu}\ x\ CF_{As}\ \ x\ CF_{Zn}} \quad (3)$$

Where; CF is contamination factor and n, number of elements

The result values were ranked as PLI < 1 (no pollution); 1 < PLI < 2 (moderate pollution); 2 < PLI < 3 (heavy pollution); 3 < PLI (extremely heavy pollution).

Enrichment Factor (EF)

Enrichment factor estimates by how much the sediment is impacted (natural and anthropogenic) with heavy metal concentrations above uncontaminated background levels as reported by Bhutiani, Kulkarni, Khanna & Ashutosh, (2017). The enrichment factor (EF) was calculated as indicated in Eq. 4.

$$EF = \frac{\left(\frac{CM}{CX_{sample}}\right)}{\left(\frac{CM}{CX_{background}}\right)} \quad (4)$$

Where; CM is the content of metal studied and CX sample and CX background are the contents of immobile element in the study area and reference, respectively. In this study, Iron (Fe) was used as conservative tracer.

Health Risk Assessment

The three major routes for exposure of heavy metals are ingestion, dermal and inhalation pathways, hence, the pathways of heavy metal exposure for this study could be through any of the aforementioned routes. The health risk assessments of the following heavy metals; Cd, Cr, Pb, Cu, As and Zn were calculated for average daily dose (ADD) as seen in Eq. 5, 6 and 7. The hazard quotient (HQ) and hazard

index (HI) as presented in Eq. 8 and 9 using the formulas prescribed by United Environmental Protection Agency (USEPA 2018). The heavy metals associated with the estimation of carcinogenic health risks are; Cd, Cr, As and Pb that can induce carcinogenesis as classified by the International Agency for Research on Cancer (IARC, 2012); meanwhile, Cd, Cr, Pb, Cu, As and Zn were included as the non-carcinogenic metals. The carcinogenic risk was calculated for lifetime exposure, estimated as the incremental probability of an individual developing cancer over a lifetime as a result of total exposure to the potential carcinogen.

$$AD_{ing} = \frac{C\ x\ IngR\ x\ Exf\ x\ ED\ x\ CF}{BW\ x\ AT} \quad (5)$$

$$AD_{inh} = \frac{\text{C x IR}_{inh}\text{ x EF x ED}}{\text{PEF x BW x AT}} \quad (6)$$

$$AD_{Der} = \frac{\text{C x CF x SA x AF x ABS x EF x ED}}{\text{BW x AT}} \quad (7)$$

Where C is mean of the metal concentration (mg/g) in surface soil samples, $IngR$ is Ingestion rate (mg/day), Exf = Exposure frequency (day/year), ED is Exposure duration (per day), BW is Body weight (per Kg), AT is Averaging time (per day), CF is Conversion factor (kg/mg), ABS is Dermal absorption factor, SA is Skin area exposed, EF is exposure frequency, PEF is Particle emission factor, IR_{ing} is inhalation rate.

Hazard Quotient for Non-Carcinogenic Risk

It is the average dose ingestion intake of each heavy metal concentrations.

$$\text{HQ} = \frac{\text{ADing}}{\text{RfD}} \quad (8)$$

Where RfD is the reference dose that characterizes the health risk of non-carcinogenic adverse effects due to exposure to toxicants, $ADing$ is the average dose ingestion.

Non-Cancer Hazard Index

Hazard index was calculated to assess non carcinogenic risk from the average dose ingestion; it is the summation of the hazard quotient for each metal concentration, both for adult and children.

$$\text{HI} = \sum_{i=1}^{n} HQ \quad (9)$$

i=1…n

Table 2.1: Values for the parameters used for the health risk assessment through different exposure pathways for soil

Symbol	Parameter	Value
Ef	Exposure frequency	350 days USEPA (2002)
ED	Exposure duration–for non-carcinogenic (adult)	24 years USEPA (2002)
	–for non-carcinogenic (children)	6 years USEPA (2002)
	–for carcinogenic	30 years US Department of Energy (2011)
BW	Average body weight (kg)–for adult	70 kg USEPA (2002)
	–for children	15 kg USEPA (2002)
AT	Averaging time	
	–for non-carcinogenic	365 x ED child or adult USEPA (2002)
	–for carcinogenic	LT of 365 days US Department of Energy (2011)
CF	Conversion Factor	1 x 10^{-6} kg/mg
IngR	Ingestion rate	
	–for adult	100 mg/day USEPA (2002)
	–for children	200 mg/day USEPA (2002)
InhR	Inhalation rate	20 mg/cm^2 USEPA (2002)
ABS	Dermal absorption factor	0.001 (unitless) USEPA (2011)
RfD	Reference Dose for Cd	0.0013 mg/kg/day USEPA (2002)
	RfD for Cr	0.0033 mg/kg/day USEPA (2002)
	RfD for Pb	0.00035 mg/kg/day USEPA (2002)
	RfD for Cu	0.03713 mg/kg/day USEPA (2002)
	RfD for As	0.0003 mg/kg/day USEPA (2002)
	RfD for Zn	0.33 mg/kg/day USEPA (2002)

AD_{ing}, AD_{inh} and AD_{der} (mg kg^{-1} day^{-1}) = average daily dose for each soil through ingestion, inhalation and dermal contact, respectively.

RESULTS AND DISCUSSION

The concentration of the metals analysed in the soil samples collected at the e-dumpsite at Atan, Ogun State, Nigeria are presented at Table 3.1. Average dose ingestion (ADD) for adults and children and hazard quotient and non-cancer hazard index for adults and children are shown in Table 3.2 and 3.3 respectively. Contamination factor and degree of contamination are presented in Table 3.4. Geo-accumulation index and enrichment factor of the heavy metals are displayed in Table 3.5. WHO permissible limits for heavy metals in soil are presented in Table 3.6.

Table 3.1 Concentration of heavy metals in soil from e-waste dumpsite in Atan

Heavy metals	Concentration (mg/kg)						
	North	South	West	East	Centre	Mean/SD	Control
Cadmium (Cd)	105.63	89.11	127.37	64.20	207.99	118.86±54.92	-17.94
Chromium (Cr)	408.57	414.83	372.42	457.73	470.47	437.9±26.68	113.64
Lead (Pb)	3582.43	7362.36	1036.89	2946.18	5378.08	3235.90±1551.50	788.25
Copper (Cu)	3993.78	3779.0	3260.36	2963.8	2962.32	3391.85±423.61	139.70
Arsenic (Ar)	217.79	215.97	228.74	149.12	250.03	208.23±36.72	6.98
Zinc (Zn)	24339.99	23785	25119.61	21035.74	24818.56	23829.78±1463.55	2098.45
Iron (Fe)	165550	175833	163607	180127	167997	169320.3±6430.26	58153.61

Table 3.2 Average dose ingestion (ADD) for adults and children

Heavy metals		Adults (mg kg^{-1} day^{-1})			Children (mg kg^{-1} day^{-1})		
	Mean	ADDing	ADDinh	ADDder	ADDing	ADDinh	ADDder
Cadmium (Cd)	118.86	1.6 E-4	2.5 E-8	3.1 E-6	1.5 E-3	1.1E-7	8.7 E-6
Chromium (Cr)	424.8	5.8 E-4	8.9 E-8	1.1 E-5	5.4 E-3	4.0 E-7	3.1 E-6
Lead (Pb)	5917.17	8.1 E-3	1.2 E-6	1.6 E-6	7.6 E-2	5.6 E-6	4.3 E-4
Copper (Cu)	3391.78	4.6 E-3	7.1 E-7	9.1 E-5	4.3 E-2	3.2 E-6	2.5 E-4
Arsenic (As)	212.33	2.9 E-4	4.5 E-8	5.7 E-6	2.7 E-3	2.0 E-7	1.5 E-5
Zinc (Zn)	23899.97	3.3 E-2	5.0 E-6	6.4 E-4	3.0 E-1	2.2 E-5	1.7 E-3

Table 3.3 Hazard quotient and non-cancer hazard index for adults and children

Metals	Adults				Children			
	HQing	HQinh	HQder	HI	HQing	HQinh	HQder	HI
Cd	1.2 E-1	1.9 E-5	2.4 E-3	1.2 E-1	1.15	8.5 E-5	6.7 E-3	1.2
Cr	1.8 E-1	2.7 E-5	3.3 E-3	1.8 E-1	1.64	1.2 E-4	9.4 E-4	1.6
Pb	2.3 E1	3.4 E-3	4.6 E-1	23.4	217.14	1.6 E-2	1.23	218.5
Cu	1.2 E-1	1.9 E-5	2.6 E-3	2.8	1.16	8.6 E-5	7.1 E-1	1.87
As	9.7 E-1	1.5 E-4	1.9 E-2	1.2 E-1	9	6.7 E-4	5.0 E-2	9.05
Zn	1.0 E-1	1.5 E-5	1.9 E-3	1.0 E-1	9.1 E-1	6.7 E-5	5.1 E-3	9.2 E-1

Table 3.4 Contamination factor and degree of contamination

Metals	Cf values	PLI	Extent of contamination	CD
Cd	-6.6	77.32	Low contamination	Low risk
Cr	3.74		Considerable contamination	Low risk
Pb	7.51		Very high contamination	Moderate risk
Cu	24.28		Very high contamination	Considerable risk
As	30.4		Very high contamination	Considerable risk
Zn	11.39		Very high contamination	Moderate risk

Table 3.5 Geo-accumulation index and enrichment factor

Metals	**Igeo**	**Description**	**Ef**
Cd	6.31`	Extremely contaminated	0.34
Cr	1.32	Moderately contaminated	0.34
Pb	2.32	Heavily contaminated	0.34
Cu	4.02	Heavily contaminated	0.34
As	4.34	Heavily contaminated	0.32
Zn	2.9	Moderately to heavily contaminated	3.42

PLI value 77.32

Table 3.6 WHO permissible limits for heavy metals in soil

Element	Permissible Limit in Soil (mg/kg)
Cd	0.8
Cr	100
Pb	85
Cu	36
As	30
Ag	NA
Zn	50

Source: WHO (1996)

The concentration of the heavy metals analysed in the soil samples collected at the e-dumpsite at Atan, Ogun State, Nigeria are presented in Table 3.1. The results of the analysis revealed that the concentration of Cd ranged from 64.20 to 207.99 mg/kg, Cr from 414.83 to 470.47 mg/kg, Pb from 1036.89 to7362.36 mg/kg, Cu from 2963.8 to 3993.78 mg/kg, As from 149.12 to 250.03 mg/kg, and Zn from 21034.74 to 25119.61 mg/kg. The mean concentration was in the order; Zn > Pb > Cu > Cr > As > Cd. Zn had the highest concentration of 2098.45 mg/kg while Cd had the lowest concentration, 64.20 mg/kg. The values of all the metals determined in the soil were higher than the control and the tolerable limits recommended by World Health Organization (WHO) as shown in Table 3.6. Zn is a necessary metal for soil, plants and humans, but it is poisonous at high concentrations, causing vomiting, appetite loss, and abdominal pain in humans. (Wuana, et al., 2011). Cadmium is a known heavy metal toxicant, and cadmium oxide fumes are absorbed through breathing. (Beata, 2014). The liver, placenta, kidneys, lungs, brain, and bones are the organs targeted for Cd poisoning. (Singh & Kalamdhad, 2011). Pb compounds are hazardous; severe Pb poisoning can cause kidney, reproductive, liver, and brain damage, as well as mortality at extremely low concentrations; other long-term effects include anemia, exhaustion, gastrointestinal difficulties, and anoxia. (Duruibe, Ogwuegbu & Egwurugwu, 2007). According to Anamika et. al., (2015). Arsenic (As) causes clinical manifestation which includes keratosis, melanosis (hyper pigmentation), leukokeratosis (hypo pigmentation). Excessive copper (Cu) exposure can induce brief gastrointestinal distress with symptoms like nausea, vomiting, and stomach pain, while high amounts of Cu exposure can damage red blood cells, resulting in anemia, as well as the liver and kidneys. (Manju, 2015). Cr (VI) causes oxidative stress by increasing the formation of reactive oxygen species (ROS), which causes genomic DNA damage and lipid and protein oxidation. (Richa, Upret, Seth, & Chaturvedi 2002). The concentration of the metals in the control sample in this study was lower than the concentration in the samples from the dumpsite. Although, the value of heavy metals in both the dumpsite and control samples were higher than the WHO permissible limits for heavy metals in soil except for Cd which was not detected in the control sample. Being an electronic waste dumpsite, the high concentrations of heavy metals can be attributed to the components of the electronic wastes such as chip resistors, infrared detectors and semiconductors. The results of the heavy metals from this finding was higher than those reported by Olafisoye et al, 2013 on

water, soil and plant around electronic waste dumpsite and Adeyi, Olayanju & Fatade (2019) on the distribution and potential risk of metals and metalloids in soil of e-waste recycling sites. In comparison with solid waste dumpsites, the levels of heavy metals in this study are higher than those in the research carried out on solid waste dumpsite by Ismat, Saif & Abubakr (2019).

The contamination factor values and the degree of contamination are illustrated in Table 3.4. The contamination factor ranged from low contamination (Cf < 1) to very high contamination (Cf < 6). The contamination factor for Cd was relatively low, Cr had a considerable contamination level while Pb, Cu, As and Zn were highly contaminated. The contamination degrees were in the range of low risk (CD < 8) to considerable risk (CD > 32). The contamination degree for the soil had low risk for Cd and Cr, moderate risk for Pb and Zn, and considerable risk for Cu and As. The pollution load index (PLI) showed that the soil around the electronic dumpsite was extremely polluted as the value calculated was 77.32, which was over seventy-seven times the safe limit of 1.

The geo-accumulation index (Igeo) and enrichment factor (Ef) of heavy metals are presented in Table 3.5. The Igeo ranged from moderately contaminated (1<Igeo<2) to extremely contaminated (≥ 5). The result showed that the soils were contaminated with all the heavy metals. However, moderately contaminated by Cr, moderately to heavily contaminated by Zn, heavily contaminated by Pb, Cu and As and extremely contaminated by Cd. Cd had the highest Igeo value of 6.31 while Cr the lowest with 1.32.

The results of the Average Daily Dose for the three exposure pathways, the hazard quotient and non-cancer risk hazard index for adults and children were presented in Table 3.2 and Table 3.3, respectively. The HI values for adults were in the following order; Pb > Cu > Cr > Cd > As > Zn while children were in the order; Pb > As > Cu > Cr > Cd > Zn. Children and adults are at high risk of Pb through ingestion pathway due to the large amount of Pb found in the soil (Ouabo et al, 2019). According to USEPA (2001), an HI value > 1 indicates possible adverse effect. In this study, the total HI values for both children and adults were 232.14 and 26.72, respectively, which are far above the USEPA safe limit. According to USEPA (2001), As, Cd, Cr, Cu, Pb and Zn have a non-carcinogenic risk while As, Cd, Cr and Pb have a carcinogenic risk. Hence, it is safe to say that all measured metals especially Pb poses significant cancer risk to adults and all except Zn which has an HI value below the safe limit, poses significant cancer risk to children. However, both adults and children were exposed to the risk of heavy metals via exposure routes.

CONCLUSION

Most electronics are made of materials that contain heavy metals, these are indiscriminately discarded on landfills, thereby, posing a great hazard effect on the soils and other living organism around. This present study assesses the health and ecological risk of heavy metals in soil around an e-dumpsite in Atan Ota, Ogun State. The result of the study revealed that the concentrations of heavy metals (Cd, Cr, Cu, Pb, As, and Zn) were significantly high, the non-cancer hazard index suggests possible adverse effect on both adults and children.

The ecological risk assessment (Cf, CD, Igeo, and PLI) reveals that the soil is polluted with low to high risk level contamination of heavy metals. In overall, the pollution indices suggest that anthropogenic activities resulted in the pollution of the study area while the health risk assessment suggests high human

exposure to heavy metals around the dumpsites. Results from the study validates that urgent measures are needed to reduce heavy metals contamination ensuing from the activities of electronic wastes at Atan, Ogun State.

It is therefore recommended that ecological assessment be carried out on other environmental counterparts such as water and plants around the e-dumpsite. The government should undertake an immense crusade against indiscriminate disposal of e-waste.

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