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Ecological Studies of Heavy Metals in E-Waste Dumpsites from Two Local Government Areas of Ogun State, Southwestern Nigeria

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ABSTRACT
The study analyzed soil samples from e-waste dumps in two local government areas of Ogun State, Nigeria, to determine the concentrations of nine heavy metals. Samples were analyzed using spectrophotometric techniques. The results were used to assess ecological health risks and conduct correlation analysis. The study found that the dumpsites had high residue concentrations of Cd, Zn, Pb, and Fe, exceeding WHO acceptable limits, also concentration of Zn and Fe at the control sites exceeds WHO limits. At the dumpsite in Ijebu-Ode, Cd had an extremely high enrichment factor of 126.67 and an Igeo of 6.400, while the dumpsites at Ijebu North, Pb had the highest enrichment factor values of 14.063 and an Igeo of 3.229 respectively which suggested severe enrichment. Therefore, the dumpsites have a high pollutant of lead. The risk index for both Ijebu North and Ijebu-Ode LGA dumpsites were 396.983 and 3916.273 respectively and thereby indicating significant risk of toxic pollution and soil contamination respectively. The high-risk index value at the Ijebu-Ode dumpsites was caused by the excessive Cd contamination in Ita-Osu. Common anthropogenic sources of the contaminants were indicated by the correlation analysis.

Keywords:
Contaminant factor,
Pollution,
E-waste,
Dumpsite,
Ecological risk.

INTRODUCTION

E-waste refers to a wide range of electrical devices including disc players, televisions, air conditioners, phones, fridge-freezers, PCs/laptops, and among others. These devices are considered inefficient, worthless, outdated, and no longer in use (Kumar *et al*., 2017; Obaje, 2013). While certain electronic waste has a high commercial value when retrieved, others are harmful and has no economic benefit. Diverse combinations metals can be found in E-waste, including hazardous and valuable ones such as iron, gold, and copper. Additionally, it consists of a heterogeneous mixture of polymers, ceramics, and glass. The level of originality and transformation of electronics and digital technology is accelerating along with its expansion. The result of this is a rise in the disposal of obsolete technologies (Olubanjo *et al.*, 2015; Muhleisen, 2018). Electronic trash can be divided into hazardous and non-hazardous materials (Kumar and Fulekar, 2017).

E-waste often contains hazardous materials such as aluminum (Al), cadmium (Cd), copper (Cu), lead (Pb), nickel (Ni) and iron (Fe), while non-toxic materials including zinc (Zn), selenium (Se) and precious metals such as silver (Ag) (Adesokan et al., 2016; Mohammed, 2013). Adaramodu *et al.* (2012), Sankhla *et al.* (2016), and Zeba *et al.* (2018) discussed the recognition of e-waste as a rapidly growing problem facing the developing countries due to inappropriate disposal. Printed circuit boards (PCBs), which are crucial components of most discarded electronic devices, are particularly noteworthy. These boards contain valuable materials, with a composition of approximately 40% metal, 30% refractory oxide, and 30% plastic, as reported by Sharma (2021). Orhan and Kadir (2014); Poopola *et al* (2019) both claimed that because of the country's rising prevalence of poverty, many scavengers in Nigeria rely primarily on the valuable parts they can salvage from electronic garbage in order to make a living, putting their health at serious risk. The improper use of extraction techniques and insufficient environmental education regarding the health challenges and electronic waste risks contribute to the current situation. Furthermore, there is a growing sense of apathy towards waste management due to a lack of awareness about the potential risks to human health posed by e-waste (Chowdury and Patel, 2017). Although toxic heavy metals are present in the environment naturally, Talabi *et al.* (2020) contended that human activities and natural processes like soil leaching and chemical weathering of rocks can increase their concentrations, having a negative impact on both human health and the environment. These toxic substances can harm delicate organs, causing diseases such as lung cancer, inflammation, brain disorders, skin diseases, blood and bone disorders, and kidney damage. They can also result in reduced mental capacity and neurological damage (Adesokan, 2016; Olafisoye, 2013).

Low standard and inexpensive e-waste management processing techniques, particularly in metal recovery from electronic equipment, are to be blame for these health problems. Scavengers employ crude recovery techniques including fire, screwdrivers, and bare hands to remove precious items from trash, endangering their health and polluting the environment in the process (Atiemo, 2012). Through ingestion, inhalation, and contaminated water that percolates through the soil, such offensive practices, as discussed by Olafisoye (2013); Bishnoi and Shah (2014), can have negative effects on people living nearby e-waste recycling sites as well as on people, animals, plants, and water (Poopola and Popoola, 2019; Fosu-Mensah *et al*., 2017). Such offensive practices, as discussed by Olafisoye (2013); Bishnoi and Shah (2014), can have detrimental effects on people living nearby e-waste recycling sites, as well as on people, animals, plants, and water through ingestion, inhalation, and contaminated water that percolates through the soil (Poopola *et al*., 2019; Fosu-Mensah *et al*., 2017). Therefore, studies on heavy metals are crucial for monitoring environmental pollution due to their negative impacts on the environment when their concentrations are slightly beyond acceptable levels. The current study was motivated by the detrimental effects of improper e-waste disposal on agricultural lands, and nearby water bodies, which have led to abandoned agricultural lands, low economic activity, and diminishing aquatic creature reproductive quality (Musa *et al*., 2013).

MATERIALS AND METHODS

Location and description of the study areas

The study area is in Ogun state, located in southwestern Nigeria. It has a total area of 16,980.55 square kilometers (6,556.23 square miles). According to the 2006 census, the state's estimated population was 3,751,140. Ogun State was established in February 1976 after separation from the former Western State (Wikipedia, 2016). Its geographical coordinates are 7° 0′ 0" North latitude and 3° 35′ 0" East longitude. Sampling locations were mainly concentrated in Ijebu-Ode and Ijebu North local governments. Ijebu Ode, located along the highway connecting Benin City and Shagamu, can be located at 6°49'8.99" North and 3°55'8.99" East. The town is known for its moderate tropical environment and had a population of over 300,000 according to the 2006 census. The local economy is supported by various industries, including printing and publishing, while artisans in the area are recognized for their skilled iron work. The primary local trade revolves around agricultural products such as yams, cassava, maize (corn), palm produce, and oranges. Additionally, rubber and timber have emerged as important commercial commodities in the region.

The Ijebu-North Local Government Headquarters, established in 1979, is in Ijebu-Igbo, located at 6°57'N 4°00'E. The area covers an area of 967 square kilometers and has a population of 284,336 people, according to the 2006 census. Ijebu North Local Government shares borders with many neighbouring areas. It is adjacent to Ijebu East local government to the north, Oluyole local government of Oyo state to the west, Ijebu North East and Odogbolu local government to the east and Ijebu Ode local government to the south. Ijebu-Igbo town is particularly famous for its timber trade, leading to the operation of many sawmills nearby.

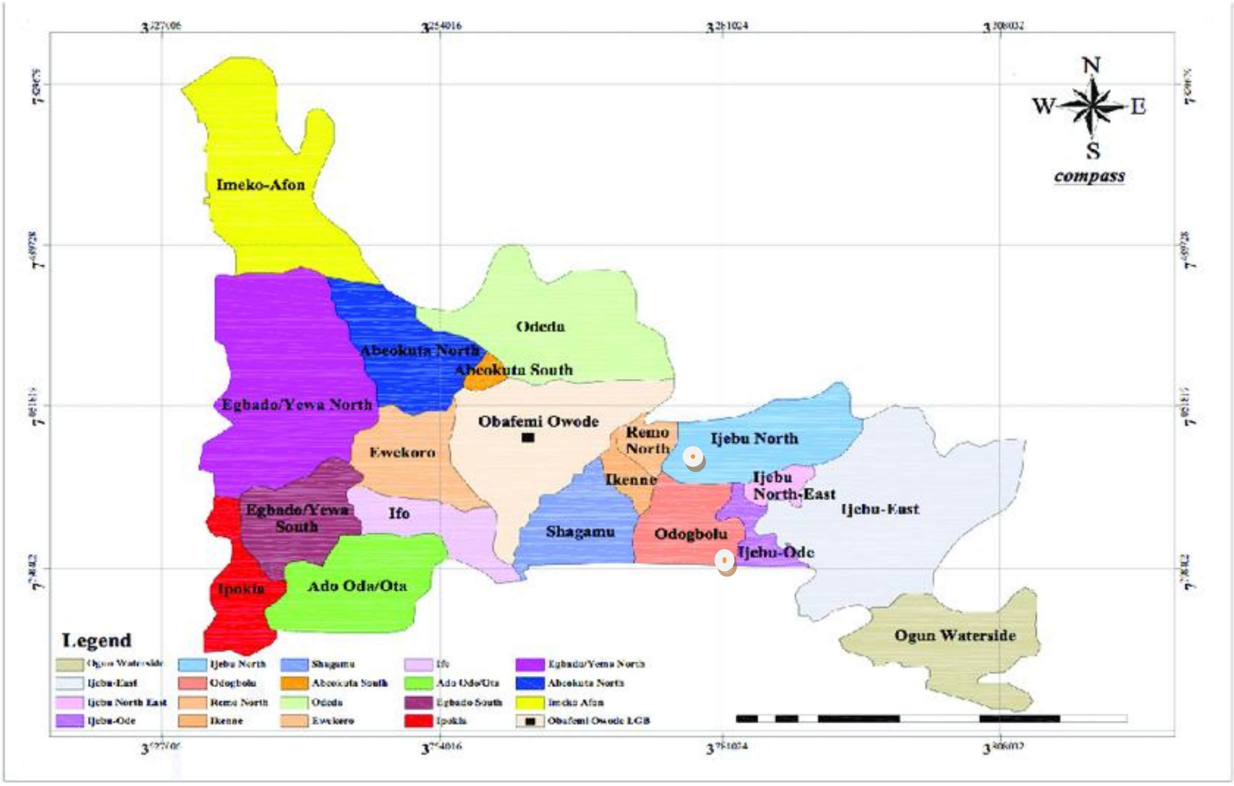

Figure 1: Ogun state Map Study area
Source: researchgate.net

Collection of samples and analysis
Soil samples were collected from several locations in Ijebu-Ode Local Government Area including Ita-Osu, Oyingbo and Imoru, three separate e-waste dumps. Additionally, a control sample was taken from Ibadan Garage in Ijebu-Ode. In Ijebu North Local Government Area, soil samples were collected from e-waste dumps in Oru and Ijebu-Igbo, along with a control sample collected from Liberty Road. These control samples were taken at a distance of two kilometers from the nearest landfill. Sampling was carried out in March 2022, specifically at e-waste dumpsites, during the dry season. Soil samples were taken at a depth of 10 cm using a drill. Then, a Buck scientific atomic absorption spectrometer with model 210 VGP specifications was used to analyze and determine the concentration level of each element present in the soil sample.
Soil samples were taken from Ita-Osu, Oyingbo, and Imoru, three different e-waste dumpsites in the Ijebu-Ode Local Government Area. There was also a control sample taken from the Ibadan garage in Ijebu-Ode. Soil samples from e-waste dumps in Oru and Ijebu-Igbo in the Ijebu North Local Government Area were collected, along with a control sample from Liberty Road. The control samples were taken two kilometers from the closest dumpsites. The sample was done especially at the e-waste dump locations in March 2022, during the dry season. A soil auger was utilized to extract samples from a 10 cm depth during sample collection. A Buck scientific atomic absorption spectrophotometer with model specification 210 VGP was then used to determine the concentration levels of each element found in the soil samples.

Digestion methods
Although, a variety of digestion techniques can be utilized for geochemical analysis, this study used the HNO_3 digestion procedure, followed by HCl extraction. 5g of each soil sample were crushed, and then sun-dried to get rid of the moisture. An electronic weighing balance was used to measure the weight of 2g of each of the crushed samples. The samples were meticulously labeled and put into a digestive tube that had been well cleaned in order to avoid contamination. Following the samples' digestion, the filtrate was examined using an atomic absorption spectrophotometer (AAS) with model specification 210 VGP from Buck Scientific.

Ecological risk assessment
Researchers have used a variety of statistical and geochemical methods to quantify the ecological dangers brought on by heavy metals in soil. These techniques include the application of indicators like the enrichment factor (EF), the index of geo-accumulation (Igeo), the

potential ecological risk index (RI), and Pearson correlation, as well as multivariate statistical studies and multivariate data. These indices allow researchers to make linkages between the quantities of heavy metals in soil samples, giving them a thorough understanding of the ecological threats these metallic elements provide.
The Index of Geoaccumulation (Igeo) serves as a tool to estimate the extent of metal pollution by comparing current metal concentrations with pre-industrial concentrations. This index provides a measure of the human impact of heavy metal pollution, such as that from e-waste. In contrast, the enrichment factor (EF) compares the observed ratio of a particular metal to a reference metal in a given sample to the background ratio of that same metal. EF is often used to evaluate the severity and status of heavy metal pollution in environmental soils. To comprehensively assess the environmental risks associated with a particular monitoring sample, researchers use the Potential Ecological Risk Index (IR). These indicators provide valuable data for identifying sources of heavy metals in soils and managing their levels, thereby improving the accuracy and reliability of ecological risk assessments.

Index of geo-accumulation (I_{geo})

The Igeo model by Zhao *et al*. (2012) is calculated using Equation (1):

$$I_{geo} = log_2 \frac{Ci}{1.5Bi} \quad (1)$$

Where the soil background value (Bi) represents the natural concentration of a specific metal in the soil, while the observed concentrations of metal i (Ci) are measured values. The reference soil background values used in this study are provided in Table 2. To consider both minor human impacts and natural variations, the recognized background value is adjusted by multiplying it by a factor of 1.5 (Adedosu *et al.*, 2013). The Geo-accumulation Index (Igeo), categorized into five levels based on its value, is used to assess contamination levels: not contaminated (Igeo≤0), lowly contaminated (0<Igeo≤1), moderately contaminated (1<Igeo≤3), considerably contaminated (3<Igeo≤5), and highly contaminated (Igeo > 5) (Zhao *et al*., 2012).

Enrichment factor

To assess the heavy metal pollution in the soil level, Enrichment Factor (EF) was developed. This study employed EF to determine the relative contributions of human and natural inputs of heavy metals to soils and to indicate the extent of contamination. To compare data from different e-waste dumpsites, metal-normalizer associations were established using control site data (Ibadan garage and Liberty road). Typically, Scandium (Sc), Manganese (Mn), Aluminum (Al), and Iron (Fe) are commonly used reference elements (Ololade, 2014). However, considering Nigeria's iron-rich soils, this investigation used Iron (Fe) as the geochemical normalizer.
EF of soil can be calculated using the equation:

$$EF = \frac{(X/_{Fe})_{soil}}{(X/_{Fe})_{background}} \quad (2)$$

where $(X/Fe)_{background}$ is the natural background value of the metal to Fe ratio and $(X/Fe)_{soil}$ is the ratio of heavy metal (X) to Fe in the soil from the dumpsites. The element is crusty if the EF value is close to unity; there may have been metal mobilization or depletion if it is less than 1.0; and the element is anthropogenic if it is larger than 1.0. Rahman's (2022) recommendations recognise and interpret five types of contamination: no enrichment is indicated by an EF value of less than 1, minor enrichment by an EF value of less than 3, moderate enrichment by an EF value of 3 to 5, moderately severe enrichment by an EF value of 5 to10, severe enrichment by an EF value of 10 to 25, and very severe enrichment by an EF value of 25 to 50, and EF greater than 50 denotes extremely severe enrichment respectively.

Risk index

To assess the total ecological danger posed by the heavy metals in the soil, an integrated Hakanson potential ecological risk index (RI) was used. This approach was chosen because the individual indicators, Igeo and EF, primarily represent the information regarding individual heavy metals, failing to account for their collective effects (Motswaiso, 2019). The value of the RI was calculated using Equation (3).

$$RI = \sum_{i=1}^{n} T_r^{i^*} \left(\frac{C^i}{C_n^i}\right) \quad (3)$$

If Ci is the metal i concentration that has been measured, T_r^i is its toxicity response coefficient, and C_n^i is its background value. Table 2 contains the T_r^i for the metals. The four levels of the risk classes' criterion are low risk (RI ≤ 150), moderate risk (150 < RI ≤ 300), significant risk (300 < RI ≤600), and severe risk (RI > 600) (Zhang *et al.*, 2022).

Statistical Analysis

To look at the relationships between the heavy metals, Pearson's correlation was used. A statistical technique called Pearson's correlation analysis is used to evaluate the link and potential strength between two variables or datasets. While a negative correlation means that when one measure falls, the other tends to grow, a positive correlation shows that both variables rise together. All of the data analysis processes used Microsoft Excel 2019 as the data analysis tool.

RESULTS AND DISCUSSION

The data in Table 1 are the findings of soil samples taken in the Ijebu-Ode and Ijebu North local government regions. These findings include heavy metal content levels in dumpsite samples that were compared to control samples. Furthermore, the concentration levels were compared to the World Health Organization's allowed limits for heavy metals in soil (WHO, 2006). Figures 1–6 give graphic representations of some heavy metals to supplement the WHO criteria. These graphical representations clearly demonstrate the relative heavy metal concentrations.

The amounts of heavy metals reported at the sample locations in Ijebu-Ode and Ijebu North are shown in Table 1. These concentrations are comparable to the World Health Organization's (WHO, 2006) standard limits for each heavy metal.

IJEBU-ODE LOCAL GOVERNMENT					**IJEBU NORTH LOCAL GOVERNMENT**				
CONCENTRATION IN SAMPLES (mg/kg)									
Elements	**Ita-osu**	**Oyingbo**	**Imoru**	**Control Ibadan garage**	**Ijebu-Igbo**	**Ijebu-Igbo**	**Oru**	**Control Liberty road**	**WHO Standard**
Cd	19.00	1.00	1.80	0.001	1.00	1.00	1.50	0.00	0.80
Cr	0.50	0.00	0.50	ND	1.50	0.50	0.50	0.00	100.00
Zn	840.00	535.00	470.00	120.00	536.00	837.00	754.00	178.00	50.00
Ni	0.00	0.00	0.00	ND	0.00	0.50	0.00	ND	35.00
Pb	94.50	278.00	160.00	1.50	225.00	19.00	14.00	9.00	85.00
Co	0.01	0.02	0.01	0.00	0.08	0.02	0.03	0.00	65.00
Fe	280.00	195.00	195.00	100.00	435.00	325.00	400.00	170.00	20.00
As	0.02	0.02	0.00	0.00	0.05	0.02	0.10	0.00	40.00
Cu	61.00	23.00	124.00	1.50	13.80	9.80	7.00	5.50	36.00

The Cd value in the Ijebu-Ode LGA e-waste dumpsite locations ranged from 1.0 mg/kg to 19.0 mg/kg. Cadmium (Cd) level was found to be as low as 0.001 mg/kg in the control location, indicating a very low concentration of this heavy metal. However, at the e-waste dumpsite, the minimum recorded result for cadmium exceeded the permissible limit set by the World Health Organization (WHO), which is 0.800 mg/kg. This indicates that the concentration of cadmium at the e-waste dumpsite poses a potential ecological risk as it surpasses the allowable limit. Conversely, at the control site, the cadmium concentration was below the WHO-permitted level, indicating a safer level of this heavy metal at that location. This suggests that the dumpsites have dangerous concentrations of Cd. The minimum and highest Cd content values at the Ijebu North LGA e-waste dumpsites were 1.00 mg/kg and 1.50 mg/kg, respectively. The concentration was as low as 0.00 mg/kg at the control locations. While the concentrations in the dumpsites were higher than the authorized limit, the concentrations at the control sites both in Ijebu-Ode and Ijebu North LGAs were lower than the WHO's acceptable level. The Cr levels at the local government e-waste dumpsites in Ijebu-Ode and Ijebu North were less than the typical allowed limit of 100mg/kg. The minimum and maximum detected concentration values for the Ijebu-Ode local government dumpsite locations were 0.00 mg/kg and 0.50 mg/kg, respectively. In the dumping areas of Ijebu North local government, the minimum concentration of Cr was 0.50 mg/kg, while the maximum concentration reached 1.50 mg/kg. Interestingly, no chromium (Cr) was detected at the Ijebu-Ode monitoring site. However, at the Ijebu North local government monitoring site, the amount of chromium (Cr) was found to be 0.00 mg/kg, indicating its absence or extremely low concentration there. Zinc (Zn) concentrations in the study area were repeatedly found to be greater than the World Health Organization's (WHO, 2006) maximum standard tolerable limit. The minimum concentration value recorded at the dumpsite locations in Ijebu-Ode local government area was 470.0 mg/kg, while the maximum value reached as high as 840.0 mg/kg. These results indicate that the Zn levels in the soil at the dumpsite locations significantly exceed the permissible limit defined by the WHO, raising concerns about potential environmental implications and ecological risks associated with such high Zn concentrations. Zn concentration levels at the control site were lower at 120.0 mg/kg, although they are still more than the allowed maximum of 50.0 mg/kg. The minimum concentration level in the Ijebu North Local Government Dumpsite locations was 536.0 mg/kg, while the maximum value was 837.0 mg/kg. A concentration level of 178.0 mg/kg, above the WHO-permitted limit, was found at the control site.

Concentration values of Ni at the research location were far lower than the WHO-permitted limit of 35.0mg/kg. At the control sites under study, Ni was not detected. The dumpsite at Ijebu-Igbo in Ijebu North LGA had the highest concentration of Ni (0.50 mg/kg). The concentration of arsenic was likewise quite low. Its concentration levels from the study were far below the acceptable WHO limit of 40.0mg/kg. Oru in Ijebu North LGA dumpsite had the highest concentration level of 0.1 mg/kg. The study area has a relatively low concentration of Co. The concentration values were much below the 65.0mg/kg WHO acceptable limit. Its highest concentration was 0.08 mg/kg in Ijebu-Igbo, in Ijebu North LGA. In both local government districts, the control sites reported 0.00mg/kg. Pb concentration levels at the Ijebu-Ode LGA dumpsite regions ranged from 94.50 mg/kg to 278.0 mg/kg, both of which are greater than the 85.0 mg/kg WHO acceptable limit. The control site has extremely low Pb value of 1.50 mg/kg indicated an adverse influence of e-waste in the concentration of heavy metals in the environment. The lowest and highest Pb concentration values at the Ijebu North LGA e-waste dumpsites were 14.00 mg/kg and 225.00 mg/kg respectively. The concentration at the control site was low, measuring 9.00 mg/kg. In both Local Government Area (LGA) regions, the concentration levels at the control sites were below the recommended limit set by the World Health Organization (WHO). However, it should be noted that the concentration levels at the dumpsites exceeded these recommended limits except Ijebu-Igbo and Oru. Furthermore, it's important to highlight that the lowest iron (Fe) level in the study area surpassed the upper limit of 20 mg/kg, as stipulated by regulations or guidelines. Concentration measurements at monitoring points in two local government areas (LGAs) have exceeded allowable limits set by the World Health Organization (WHO). At the same time, landfills have significantly higher concentration values. In Ijebu-Ode LGA, concentrations ranged from a minimum of 195.0 mg/kg to a maximum of 280.0 mg/kg. In Ijebu North LGA, landfills had even higher concentrations, with a minimum of 325.0 mg/kg and a maximum of 435.0 mg/kg. Notably, the Fe (iron) content in the dumpsites in Ijebu North LGA was significantly higher than that in the dumpsites in Ijebu-Ode LGA.

The average Cu content levels of the Ijebu-Ode dumpsites surpassed the 36.0mg/kg limit. In Imoru, the minimum concentration is 23.0 mg/kg and the maximum concentration is 124 mg/kg. Cu concentration is extremely low (1.50 mg/kg) in the control location. The concentration levels at the Ijebu North Local Government dumpsite regions, on the other hand, were lower than the permitted legal limit of 36.0 mg/kg. The lowest value was 5.50 mg/kg at the control site, whereas the highest value from the dumpsites was 13.80 mg/kg in Ijebu-Igbo. Findings from this study showed that due to years of electronic waste and trash disposal at these locations, the area surrounding the dumpsites has a greater concentration of heavy metals especially Cd, Zn, Pb and Fe than the control sites.

Table 2 summarizes the ecological risk assessment of the research findings. The purpose of this evaluation was to identify the relative contributions of anthropogenic and natural sources of heavy metal inputs to the soil, as well as to estimate the amount of contamination. The Risk Index (RI) was used as a broad metric to quantify the total ecological danger presented by all heavy metals in the soil. By utilizing this index, the study aimed to gain insights into the potential environmental impacts and hazards associated with the presence of heavy metals in the soil.

Table 2: Illustrates the heavy metal ecological risk assessment indices at e-waste dumpsites

Heavy metal	EF	Control (mg/kg)	Maximum (Ci)(mg/kg)	(Bi) (mg/kg)	Igeo	T_r^i	RI
			IJEBU-ODE LGA DUMPSITES				
Cd	126.667	000.001	019.000	000.150	006.400	030.000	3800.000
Cr	000.004	ND	000.500	122.000	-008.516	002.000	000.008
Zn	011.200	120.000	840.000	075.000	002.9004	001.000	011.200
Ni	-	ND	000.000	-	-	005.000	000.000
Pb	017.375	001.500	278.000	016.000	003.534	005.000	086.875
Co	-	000.000	000.010	-	-	-	000.000
Fe	001.867	100.000	280.000	150.000	000.3155	005.000	009.333
As	-	000.000	000.020	-	-	010.000	000.000
Cu	001.771	001.500	124.000	070.000	000.240	005.000	008.857
		RI = 3916.273					
			IJEBU NORTH LGA DUMPSITES				
Cd	010.000	000.000	001.500	000.150	002.737	030.000	300.000
Cr	000.012	000.000	001.500	122.000	-006.931	002.000	000.025
Zn	011.160	178.000	837.000	075.000	002.895	001.000	011.160

Ni	-	ND	000'000	-	-	005.000	000.000
Pb	014.063	009.000	225.000	016.000	003.229	005.000	070.312
Co	-	000.000	000.085	-	-	-	000.000
Fe	002.900	170.000	435.000	150.000	000.951	005.000	014.500
As	-	000.000	000.020	-	-	010.000	000.000
Cu	000.197	005.500	013.800	070.000	-002.927	005.000	000.986
RI=396.983			**RI=396.983**				

Ijebu North has an Igeo of 2.737, indicating moderate impurities, and an EF of 10, indicating moderate and severe enrichment. Cadmium in the Ijebu-Ode e-waste dumpsites had an Igeo of 6.400, indicating that the soil was largely contaminated, and an extremely high EF of 126.67, indicating extremely severe enrichment.

This demonstrates how seriously contaminated Cadmium treatment sites are.

At the e-waste dumpsites of Ijebu-Ode and Ijebu North local governments, Cr had Igeo values of -8.516 and -6.931, indicating the absence of impurities, and EF values of 0.004 and 0.012, indicating There is no enrichment process. This proves that the soil is not contaminated with Cr. The Ijebu-Ode and Ijebu North dumpsites have essentially the same ecological indicators. Zn, at the Ijebu-Ode and Ijebu North landfills, had independent EF values of 11.2 and 11.16, indicating significant enrichment. The Igeos were 2.9004 and 2.895, respectively, indicating moderate impurities. This shows that e-waste landfills are contaminated with Zn. The ecological indicators for Pb at the dumpsites in Ijebu-Ode and Ijebu North were comparatively alike. The EF was 17.375 and 14.06, respectively, suggesting severe enrichment, while the Igeo was 3.534 and 3.229 respectively, showing significant contamination. This further demonstrates the Pb pollution of the e-waste dumps. Although, Fe concentrations were above the WHO acceptable limit, it showed modest contamination with an Igeo of 0.3155 and a little enrichment with an EF value of 1.867 at the Ijebu-Ode e-waste dumpsites. It had low contamination factor (Igeo of 0.951) and slight enrichment (EF of 2.900) values at the Ijebu North dumpsites. This reveals that there is little to no Fe contamination at the dumpsites. Fe was employed as the geochemical normalizer in this study because it has been widely reported that the soil in Nigeria is rich in Fe (Ololade, 2014). The Igeo value for Cu at Ijebu North LGA was -2.927 which indicated no pollution. This is in contrast with the Igeo value of 0.240 at Ijebu-Ode LGA dumpsites which showed minimal contamination. Ijebu-Ode LGA had an EF of 1.771, suggesting moderate enrichment as compared to Ijebu North's EF of 0.197, which indicated minimal enrichment. This reveals that the Ijebu North dumpsites were not Cu-polluted. The RI for the heavy metals content at the Ijebu North LGA dumpsites was 396.983, demonstrating a huge risk of poisonous contamination. At Ijebu-Ode LGA e-waste dumpsites, the RI value was extremely high at 3916.273 which indicated a high toxic risk of soil contamination. The high RI value at the Ijebu-Ode dumpsites was caused by the excessive Cd contamination in Ita-osu. Ni, Co, and As did not undergo an ecological risk assessment because of the research area's extremely low concentration of these elements. It is reasonable to assert that the dumpsites won't be impacted by any potential hazards that the metals may have.

Health effects of heavy metals that are above the permissible limit

Small doses of the hazardous Cd metal can have harmful effects on people. It is one of the hazardous heavy metals mostly found in soil in Nigeria (Talabi *et al.*, 2023). The presence of Cd in the soil contributes to a number of environmental catastrophes, such as sea salt spray, volcanic eruption, weathering, and wildfires (Dutta *et al.*, 2020). The prostate, kidney, lungs, liver, heart, salivary glands, and epididymis are just a few of the organs where Cd are absorbed into by humans. This causes these organs to fail and speeds up human mortality. Numerous enzymes in the body are known to be negatively impacted by cadmium, and it is thought that cadmium's negative effects on these enzymes are what cause proteinuria and renal damage (Dutta et al., 2020). It is well recognized that it can cause cancer in people. Batteries, aviation corrosion-resistant and light-sensitive resistors, and PVC are the main sources of Cd in e-waste (Ofudje *et al.*, 2018). Cadmium is a toxin that can build up over time and is hazardous to the human body, especially the kidneys. The Cd content in this study is comparable to those found in (Ofudje *et al.*, 2018; Abiaziem *et al*., 2022; Adewumi *et al*., 2017). Zinc plays a crucial role in the body despite not being naturally produced by the body. It supports gene expression, immunological function, wound healing, and protein synthesis. However, prolonged exposure to zinc fumes or dust can cause metal fume fever, a transient illness. Continuous exposure to levels over the permissible upper intake range may impair immunity, lower levels of HDL cholesterol, and result in copper deficiency (Adewumi *et al*. 2017). Additionally, copper is a crucial trace metal that is necessary for enzyme systems, which are in charge of the numerous metabolic activities necessary to maintain life. The accumulation of too much copper in the body can lead to a variety of diseases and health issues, including anorexia, headaches, migraines, arthritis, and constipation. In living things, lead plays no significant biochemical significance (Talabi *et al.*, 2023). High Pb soil concentrations may cause plants and food crops to absorb more Pb, which could then cause bioaccumulation and biomagnifications in the food chain. The two main exposure methods are inhalation and ingestion, and both have similar effects, particularly when it builds up in the body (brain, neurological system, red blood cells, kidney), which may cause death or plumbism. Children exposed to it run the risk of mental decline, decreased development, reduced IQ, shortened attention span, hyperactivity, and damage to the kidneys, gastrointestinal tract, and central nervous system. When exposed to Pb, adults typically suffer from impaired reaction time, memory loss, nausea, sleeplessness, anorexia, and joint weakness (Iwuchukwu *et al.*, 2018)

Pearson's correlation analysis

The association between the heavy metal contents from each of the LGA e-waste dumpsites was established using Pearson's correlation analysis as shown in Table 3.

Table 3: depicts the Pearson's correlation indices between the heavy metals at the study areas.

	Cd	Cr	Zn	Ni	Pb	Co	Fe	As	Cu
					IJEBU-ODE LGA DUMPSITES				
Cd	1.0000								
Cr	-0.5000	1.0000							
Zn	0.2510	-0.9640	1.0000						
Ni	-	-	-	1.0000					
Pb	-0.7970	-0.9360	-0.6580	-	1.0000				
Co	-0.7210	-0.9710	-0.5650	-	0.9930	1.0000			
Fe	0.9990	0.5000	0.9860	-	-0.7730	-0.6930	1.0000		
As	0.4660	-0.5000	0.6360	-	0.1630	0.2770	0.5000	1.0000	
Cu	-0.1020	0.7870	-0.3020	-	-0.5190	-0.6150	-0.6150	-0.9280	1.0000
					IJEBU NORTH LGA DUMPSITES				
Cd	1.0000								
Cr	-0.5000	1.0000							
Zn	0.2510	-0.9640	1.0000						
Ni	-	-	-	1.0000					
Pb	-0.5180	1.0000	-0.9580	-	1.0000				
Co	-0.3990	0.9940	-0.9880	-	0.9910	1.0000			
Fe	0.2050	0.7450	-0.8960	-	0.7310	0.8150	1.0000		
As	0.9290	-0.1430	-0.1270	-	-0.1630	-0.0300	0.5540	1.0000	
Cu	-0.8110	0.9120	-0.7700	-	0.9210	0.8600	0.8600	-0.5360	1.0000

From the primary pollutants investigated at Ijebu-Ode dumpsites, Cd/Fe, Zn/Fe, and Pb/Co, showed a relatively high positive connection. Additionally, there is a strong negative association between Cd/Pb, Cd/Co, Cr/Pb, Cr/Co, and Pb/Fe and As/Cu. There is a strong positive link between Cd/As, Cr/Cu, Cr/Co, Pb/Co, Pb/Cu, Co/Fe, Co/Cu, Fe/Cu at the Ijebu North dumpsites. The strong positive connections that were found in this investigation suggest that the heavy metals came from anthropogenic sources that were widespread.

CONCLUSION

The analytical results of this study showed that the soil sampled from Ijebu-Ode and Ijebu North LGAs were heavily contaminated with Cd, Zn, Pb and Fe, indicating that the sites, especially the soil sampled from the Ita-Osu dumpsite can cause risks to human health, animals and the food chain. The EF, Igeos and RI results indicate that heavy metal contamination, especially Cd, is quite common in these locations. Heavy metal pollution is quite common at this research sites. The range of heavy metal contents in this study is comparable to the published values from e-waste dumpsites described by (Ofudje et al., 2018; Abiaziem et al., 2022; Adewumi et al., 2017). The correlative investigation showed that the pollutants were all caused by humans.

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