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ORIGINAL ARTICLE

Evaluation of Heavy Metal Accumulation at Ebonyi Waste Recycling Dumpsite and Health Implications to Surrounding Population

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Abstract
This study evaluated heavy metal accumulation and contamination at the Ebonyi State solid waste recycling dumpsite and the impact to surrounding population. Soil samples obtained from different locations in the dumpsites, surrounding farms and control sites were assessed for toxic heavy metal concentration and compared with values from the control site. The Average heavy metals concentration in soil samples were evaluated with Atomic Absorption Spectrophotometer (AAS). The heavy metal concentration analysis revealed that average heavy metal concentration of the dumpsites and surrounding farmland for Cr, Cd, Co Pb, Ni, Zn, Cu, As, Fe, and Hg were found to be 0.035, 0.21, 0.53, 2.265, 0.44, 0.675, 0.78, 0.035, 3.41 and 0.03 mg/kg respectively. The concentration of heavy metals in studied samples showed that Pb > Fe > Cu > Zn > Co > Ni > Cd > Cr > Hg > As. Soil contamination evaluation analysis was based on geo-accumulation index (I_{geo}), Potential ecological risk coefficient (RI), Chronic daily take (CDI), Total carcinogenic risk index (TCRI), Total hazard quotient (THQ) and pollution load index (PLI). The average values of I_{geo}, CDI, TCRI, THQ and PLI for dumpsites and surrounding farms were found to be 2.01, 207.19, 6.1×10^{-2}, 2.66, 0.95 and 1.33 respectively. Generally, high concentrations of Pb and Fe were observed at the dumpsites and surrounding farmlands. Comparing mean values of heavy metal contamination at the dumpsite and the farmland with the control site, Ebonyi state solid waste management and recycling dumpsite and the surrounding farmland do not pose any immediate carcinogenic risk to workers and residents in the surrounding population. However, there is need for constant monitoring of heavy metal contamination of the dumpsite and surrounding farmlands.

Keywords Heavy metals · Geo-accumulation index · Potential ecological risk · Total carcinogenic risk index · Pollution load index

1 Introduction

Human beings, plants and animals are constantly exposed to natural and man-made environmental hazards. This could be from contamination by heavy metals caused by human activities within an environment (Rahman et al. 2022). These environmental hazard emanating from heavy metals such as Lead (Pb), Copper (Cu), Zinc (Zn), Cadmium (Cd), Iron (Fe), cobalt (Co) Arsenic (As), Nickel (Ni), Chromium (Cr) and Mercury (Hg) from unprocessed waste materials penetrate the underground soil and leached into the adjoining farmlands (Ogbonna et al. 2021; Luo and Jia 2021; Wong et al. 2003). These non-degradable heavy metals accumulate in the soil. Based on the bioavailability of the heavy metals, they are easily transfer to the human body via food chain (Burges et al. 2015; Guney et al. 2010; Nobi et al. 2010). Although, some heavy metals, like as Cu, Fe and Zn have proved to be helpful to human health as essential mineral elements in the body, as they play important role in body metabolism. However, these heavy metals could be toxic to human systems when they are ingested in excess (Liu et al. 2013; Eshaimi et al. 2012).

Recently, heavy metal contamination has increased due to high human and industrial activities in Ebonyi State, Nigeria. Waste generation, disposal and recycling have greatly contributed to the increased in levels of heavy metal contamination (Jibiri et al. 2014). The understanding of toxic heavy metal accumulation and

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contamination at waste management and disposal sites will enhance on-the-spot assessment of possible environmental hazard on human and animal health due to waste disposal and management activities.

Recent studies have shown that population growth, industrialization and mining activities in Ebonyi state, Nigeria have greatly increased human health risk through heavy metal accumulation and contamination. Therefore, this study is crucial for proper human health risk assessment of the dumpsite and the health effect to the surrounding population. According to the Environmental Protection Agency (EPA) and Agency for Research on Cancer (IARC), exposure to inorganic arsenic and toxic heavy metals are of major concern for healthy environment due to their carcinogenic and non-carcinogenic effects on human health (Alidadi et al. 2019; Onyedikachi et al. 2018).

The absence of data on heavy metal concentration of waste management sites and surrounding farmlands in Ebonyi State Nigeria, for routine and systematic monitoring of the health and environmental impact around this dumpsite has also necessitated this research. This research, will in no small measure, facilitate the constant monitoring of heavy metal concentration, levels of the dumpsite under consideration, ignite meaningful conversation around municipal waste management and forestall possible environmental hazard within this site. It will also enable government / Environmental protection agencies to make appropriate legislation for efficient waste management and disposals bearing in mind the health implications of heavy metals in farmlands and in surrounding water bodies within the dumpsite.

Some researchers in Nigeria have assessed heavy metal concentration (Antigha et al. 2013; Ebong et al. 2008) at different dumpsites and strategic locations. These researchers include (Avwiri and Olatubosun 2014; Faweya and Babalola 2010; Emelue et al. 2013; Oladapo et al. 2012) etc.

The results of most of these researches have shown that concentration of heavy metal is usually greater at upper soil layer than at the lower soil layer. This has increased the possibility of root crops absorption of these metals and subsequent transfer to human systems through the food chain. Generally, there were substantial increase in heavy metal concentration at most dumpsites relative to control sites. However, further assessment and constant monitoring of heavy metal concentration levels at these waste management and dumpsites is necessary to predict future hazard due to increase in industrial and human activities around these dumpsites.

The main objective of this research is to monitor and evaluate the level of heavy metal concentration in soil samples at the Ebonyi State solid waste recycling dumpsite and the surrounding farmlands. The result obtained shall be analyzed to determine the nexus between environmental contaminations by heavy metals with intermittent health challenges observed in the community where the dumpsite is located. This will be achieved by evaluating the heavy metal contamination on people living around the dumpsite and the inherent risk connected with the consumption of crops and food polluted by heavy metals within that location. Findings from this study shall assist Ebonyi State government, through the Ministry of Health and Environment and other environmental protection agencies to produce baseline data on heavy metal monitoring initiatives with respect to Ebonyi state, Nigeria. The results shall also provide a reference guideline for future heavy metal concentration analysis within and around Ebonyi State solid waste management and recycling plant.

2 Theoretical background

2.1 Geo-accumulation Index (I_{geo})

Geo-accumulation index is the evaluation of heavy metals concentration in soil (Colak 2012; Sutherland 2000; Muller 1969). It is evaluated using Eq. 1

$$I_{geo} = \mathrm{Log}_2\left[\frac{C_n}{1.5B_n}\right] \tag{1}$$

C_n represents concentration in mg/kg of n heavy metal; B_n represents geochemical background value concentration of average continental shale. While 1.5 is a constant factor which corrects background matrix variation from lithogenic effects according to Agca and Ozdel (Agca and Ozdel 2014). Geo-accumulation index is categorized into seven (7) (Pelfrene et al. 2013) (see Table 1).

2.2 Potential Ecological Risk Assessment (PER) / Contamination factor (CF)

PER also referred to as contamination factor (CF) is a factor which expresses the impact of heavy metal

Table 1 Geo-accumulation index categorization

I_{geo}	Pollution load index	Degree of contamination
$I_{geo} < 0$	0	Background concentration
$0 \le I_{geo} \le 1$	1	Uncontaminated
$1 \le I_{geo} \le 2$	2	Moderately contaminated to uncontaminated
$2 \le I_{geo} \le 3$	3	Moderately contaminated
$3 \le I_{geo} \le 4$	4	Moderately to highly contaminated
$4 \le I_{geo} \le 5$	5	Highly contaminated
$I_{geo} \le 5$	6	Very highly polluted

contamination in soil due to the sediment nature a heavy metals and its environmental characteristics. Potential ecological risk coefficient gives the toxicological effect of heavy metal concentration in any ecological environment (Rahman et al. 2019). It is evaluated with Eqs. 2, 3 and 4.

$$PC = \frac{C_n}{B_n} \quad (2)$$

$$PER = PCxT_r \quad (3)$$

$$RI = \sum_{i=1}^{n} PER \quad (4)$$

where C_n and B_n maintain their early established definitions.

PER gives the potential ecological risk coefficient for a specific heavy metal in an environment under consideration; T_r is the parameter which gives the toxic response factor of a heavy metal. According to the Hakanson standard (Hakanson 1980). It recognized T_r of Hg as 40, Cr as 2, Cd as 30, As as 10, Pb as 5, Cu as 5, Zn as 1, and Ni as 5. RI is the potential ecological risk coefficient which gives the impact of considered heavy metal contamination in soil of a particular environment. Potential ecological risk coefficient is classified as shown in Table 2 below.

2.2.1 Pollution Load Index (PLI)

A PLI greater than 1 implies heavy metal pollution exists while a value less than 1 implies no heavy metal pollution. PLI of the investigated area was determined by calculating the n root of products of the n CFs using Eq. 5 (Oluwatuyi et al. 2020).

$$PLI = (CF_1xCF_2xCF_3x \dots xCF_n)^{\frac{1}{n}} \quad (5)$$

n represents number of heavy metals under consideration investigated (n = 10) this index offers a simple and elegant means for evaluating the extent of heavy metal contamination. This contamination or pollution levels are categorized on a scale of 1 to 6, based on pollution intensity (0 = none, 1 = none to medium, 2 = moderate, 3 = moderately to strong, 4 = strongly polluted, 5 = strong to very strong, 6 = very strong) (Muller 1969).

2.3 Human Health hazard Assessment due to Presence of Heavy Metal

Human health risk assessment techniques considered in this research were for Non-carcinogenic and carcinogenic hazards as explained by Muhammad et al. (2011).

2.3.1 Non-Carcinogenic Assessment

Health risk assessment based on heavy metals present in an environment provides the noncarcinogenic and carcinogenic hazards on a human body due to constant ingestion, inhalation or body contact (epidermal) to heavy metals (Ezeh and Anike 2010; Meza-Montenegro et al. 2012). Based on relevant standards recognized by the United States Environmental Protection Agency (USEPA) (1989, 1996, 2002), the total potential non-carcinogenic health risk due to heavy metals exposure in soil is obtained by evaluating the THQ.

THQ is the summation of ratios between the reference dose (RfD) and Chronic Daily Intake (CDI) of each element. In this study, the RfD of each element was adopted from USEPA screening levels (USEPA 2010). The exposed population is assumed to be safe when HQ lower than 1(Alidadi et al. 2019).

Hazard index or Total hazard quotient (THQ) is calculated with Eqs. 6 and 7 (USEPA 1996, 2002).

$$HQ = \frac{CDI}{RFD} \quad (6)$$

$$THQ = \sum_{k=1}^{n} HQ = HQ_{Cr} + HQ_{Cd} + HQ_{Co} + HQ_{Pb} + HQ_{Ni} + HQ_{Zn} + HQ_{cu} + HQ_{As} + HQ_{Fe} + HQ_{Hg} \quad (7)$$

THQ value ≤ 1, implies absence of noncarcinogenic health risk. THQ value > 1 implies potential noncarcinogenic health risk, which means higher likelihood of causing harmful health impacts to the human body. The higher the THQ value, the greater the health risk.

Table 2 PER coefficient classification

Ecological risk level	Low	Moderate	Considerable	High	Significantly high
PER	< 40	41 – 79	80 – 159	160 – 319	> 320
RI	< 150	151 -300	301- 599	≥ 600	-

2.3.2 Carcinogenic Risk Index (CRI) Assessment

The CRI and Total carcinogenic risk index (TCRI) give the possibility of displaying any form or symptom of cancer by an individual in a lifetime usually 70 years averages due to constant contact or exposure to carcinogenic heavy metal (Qasemi et al. 2018; Sultana et al. 2017). Equation 8 was applied in the computation of TCRI.

$$TCRI = \sum CRI = CDIxCSF \tag{8}$$

where CSF provides the cancer slope factor. The CSF is the generated risk due to lifetime exposure to carcinogenic chemical at the average rate of one mg/kg per day.

The CDI of heavy metals is the mass of heavy metal that is in contact with a body weight, per unit time. It is expressed and evaluated with Eq. 9 (USEPA IRIS 2011; Kamunda and Madhuku 2016).

$$CDI = \frac{C_n xIRxEFxED}{B_w xA_T} \tag{9}$$

C_n in mg/kg is the concentration of heavy metals in the location, IR is the Ingestion rate, EF is the Exposure frequency, ED is the Exposure duration, B_W is the Body weight, A_T is the Averaging Time.

If TCRI value is less than 10^{-6}, this implies there is no carcinogenic risk. However, if TCRI value is greater than 10^{-4}, this implies the high probability that heavy metals will cause cancer risk to human body. Single carcinogenic metals and multi carcinogenic metals have permissible limits of 10^{-6} and less than 10^{-4} respectively (Tepanosyan et al. 2017; Ahmad et al. 2021). Table 3 shows the Input parameter applied in calculating CDI values *USEPA* (2006; USEPA 2004).

The values of parameters applied in the computation of the values of CSF and RfD through ingestion are displayed in Table 4 (USEPA 2006).

Table 3 Input parameters for computation of CDI value

Parameter	Symbol	Unit	Adult
Ingestion rate	IR	mg/dose	3.0
Exposure frequency	EF	Dose/year	350
Exposure Duration	ED	Years	30
Body weight	Bw	Kg	70
Averaging time	$A_T(ED \times 365)$	Days	10950

Table 4 Soil heavy metals CSF and RfD values for ingestion exposure pathways

Heavy metals	CSF(mg/kg/day) Ingestion	RfD (mg/kg/day) Ingestion
Cr	0.5	3×10^{-3}
Cd	6.1	1×10^{-3}
Co	-	2×10^{-3}
Pb	8.5×10^{-3}	3.5×10^{-3}
Ni	0.91	2×10^{-2}
Zn	-	3×10^{-1}
Cu	-	4×10^{-2}
As	1.5	3×10^{-4}
Fe		3×10^{-3}
Hg	-	1.6×10^{-4}

3 Materials and Methods

3.1 Study Area

The study was carried out at the Ebonyi State solid waste recycling plant dumpsite, and the surrounding farmlands located at former Abakaliki forest reserve in Enyim community of Ezza North Local government of Ebonyi State, Nigeria (see Figs. 1 and 2). The waste recycling dumpsite was cited on a land area of 2.5 sq. Km. which lies between 6.353536N and 8.044732E and surrounded by farmlands and housing estate. Sampling sites / locations were geographically identified using Global Positioning System (GPS). The dumpsite was designed to receive solid waste from Abakiliki metropolis and its environs before moving to the recycling plant. The dumpsite receives waste materials estimated at 12 tons per month. The high level of human activities, the quantity of waste dumped as well as the proximity of the dumpsite to the surrounding farmlands and a housing estate makes the dumpsite and the surrounding farmlands an important site for environmental hazards assessment studies because of suspected risk of heavy metals contamination in the farmland.

3.2 Sample Collection and Preparation

400 g of soil samples were randomly collected from five (5) different points on the dumpsite and five (5) different points on the surrounding farmland on 6th November, 2023. Soil samples were collected with metal trowel and after each

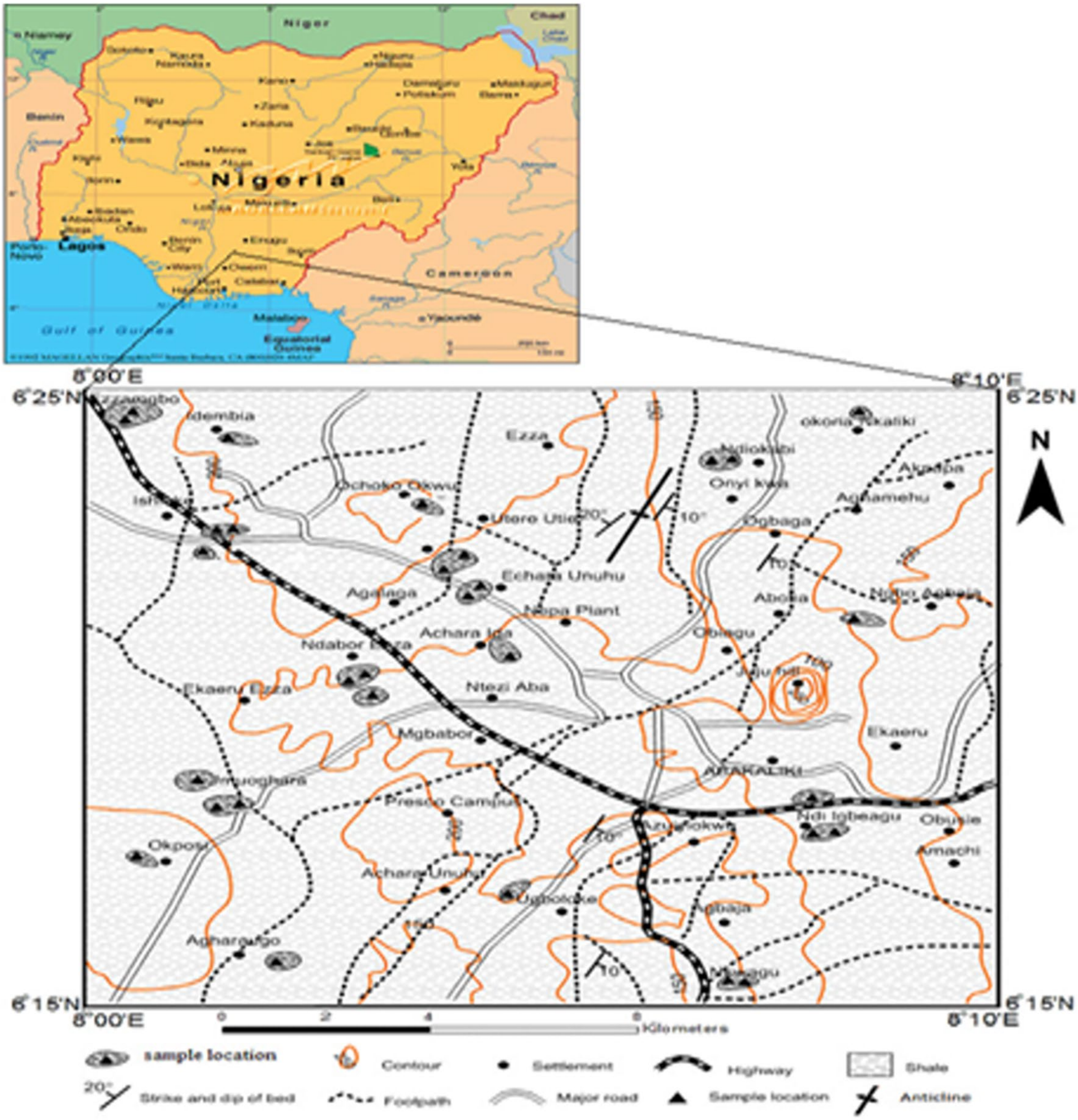

Fig. 1 Map of Abakaliki Metropolis

sample collection, the metal trowel was thoroughly cleaned several times with deionized water to prevent interference and cross-contamination. Soil samples were collected within the upper soil layer of 0 – 5 cm (Agca and Ozdel 2014). This soil layer was selected because most biogenic and anthropogenic contaminants settle down within this depth (Krishna and Govil 2007; Radomirovic et al. 2020). Two control samples were collected from a nearby forest reserve 500 m from the center of the dumpsite which is free from waste disposal and other human activities. All collected samples were analyzed for heavy metals concentration. Number of samples collected was based on the size of the dumpsite and the adjoining farmland. The sampling points were carefully selected to include areas with high human activities.

3.3 Measurement of Toxic Heavy Metal Concentration

All samples were separately packed, labeled and immediately conveyed to laboratory.

At the laboratory, all samples were sun dried for seven (7) days to reduce moisture. Thereafter, samples for activity concentration test were pulverized by grinding, sieved through a mesh sieve 2 mm to achieve homogeneity. The homogenized soil samples were then oven-dried at 120 °C for 10 h until they attained constant weight and subsequently measured using an electronic weighing balance. Soil samples were packaged and taking to Aluminum smelting company of Nigeria (ALSCON) for the

Fig. 2 Ebonyi State waste recycling dumpsite

evaluation of heavy metals (Fe, Cu, Pb, Zn, As, Co, Cd, Cr, Hg and Ni) concentration using Unicam 939 model of Atomic absorption spectrometer (AAS). In the laboratory, each of the sample were subjected to microwave-assisted processing at 175 °C. 0.5 g of each sample were digested in 8 ml mix of concentrated, HCl, HNO_3 in the ratio of (2:7). Very little quantity of hydrogen peroxide (H_2O_2) was slowly added in each of the sample solution to reduce the volatile behavior of the acidic reaction in the test tube. Thereafter, each of the sample solutions were diluted with distilled water, chilled and filtered using Whatman filter (No.41) paper, and stored in an acid sterilized tubes at 5 °C before the evaluation of heavy metals concentration.

These measurements were carried out in duplicate. The relative standard deviation between similar analyses were less than 4% which is within an acceptable level of accuracy (Agca and Ozdel 2014). International Certified reference materials (Loam Soil C, Lot No. 707904) obtained from the National Institute of Standards and Technology (NIST) were applied as standard samples for the purpose of quality assurance and control. Recovery rates for heavy metals in the standard reference material were between 80 and 115%. The minimum detection limit (MDL) for each evaluated sample Cr, Cd, Co Pb, Ni, Zn, Cu, As, Fe, were obtained at 1.3 mg/kg, 0.4 mg/kg, 0.6 mg/kg, 2.1 mg/kg, 1.5 mg/kg, 0.07 mg/kg, 0.6 mg/kg, 0.04 mg/kg, 1.8 mg/kg and respectively. The sequence of atomic absorption spectrometer comprised of a quality controlled sample and a blank sample which was introduced after 8 samples analysis. Atomic fluorescence spectrometer (AFS-9760) was applied in mercury concentration evaluation using Hydride generation/ cold vapor fitment (Radomirovic et al. 2020). The MDL for Hg was observed at 0.03 mg/kg (Table 5).

Table 5 Heavy metal concentration in soil samples from Ebonyi state solid waste recycling dumpsites and surrounding farmland

Site	Area	Heavy metal concentration (mg/kg)									
		Cr	Cd	Co	Pb	Ni	Zn	Cu	As	Fe	*Hg
Location 1 (0 – 5 cm)	Dumpsite	0.06	0.18	0.56	3.05	0.21	0.94	1.01	0.04	5.92	0.02
Location 2 (0 – 5 cm)	Dumpsite	ND	0.24	0.72	3.20	0.62	1.04	0.96	ND	4.54	ND
Location 3 (0 – 5 cm)	Dumpsite	0.04	0.36	0.84	2.36	0.84	0.80	0.74	ND	4.35	0.04
Location 4 (0 – 5 cm)	Dumpsite	0.03	0.21	0.41	2.49	0.80	1.08	0.61	0.02	3.89	ND
Location 5 (0 – 5 cm)	Dumpsite	ND	0.41	0.61	3.77	0.72	0.72	0.81	0.06	4.29	0.02
Average value(Dumpsite)		**0.04**	**0.28**	**0.63**	**2.98**	**0.64**	**0.92**	**0.83**	**0.04**	**4.60**	**0.02**
Location 6 (0 – 5 cm)	Farmland	ND	0.10	0.31	2.11	0.40	0.82	0.92	0.03	2.45	ND
Location 7(0 – 5 cm)	Farmland	0.02	0.20	0.41	1.20	0.11	0.41	0.81	ND	2.34	ND
Location 8(0 – 5 cm)	Farmland	ND	0.15	0.51	1.44	0.16	0.32	0.62	ND	1.94	0.04
Location 9 (0 -5 cm)	Farmland	ND	0.09	0.42	1.32	0.32	0.50	0.91	0.02	2.06	ND
Location10 (0 – 5 cm)	Farmland	0.04	0.14	0.50	1.68	0.22	0.12	0.40	ND	2.31	ND
Average value(Farmland)		**0.03**	**0.14**	**0.43**	**1.55**	**0.24**	**0.43**	**0.73**	**0.03**	**2.22**	**0.04**
Dumpsite & Farmland Average Value		**0.035**	**0.21**	**0.53**	**2.265**	**0.44**	**0.675**	**0.78**	**0.035**	**3.41**	**0.03**
Control sample 1		ND	0.08	0.30	0.98	0.20	0.04	0.20	ND	1.06	ND
Control sample II		ND	0.05	0.25	1.04	0.13	ND	0.20	ND	1.00	ND
Average control sample		**ND**	**0.065**	**0.275**	**1.01**	**0.165**	**0.04**	**0.2**	**ND**	**1.03**	**ND**
WHO acceptable range of heavy metal in soil (mg/kg). Meza-Montenegro (2012)		**0.002 - 0.2**	**0.02 - 0.5**	**0.04–0.2**	**0.3 - 10**	**0.1—5**	**12—60**	**1—12**	**0.09 – 1.5**	**-**	**0.001 - 0.04**

ND – not detected. *—(μ/Hg)

Table 6 Summary of heavy metal contamination assessment for dumpsite and farmland

LOCATION	I_{geo}	RI	CDI	TCRI	THQ	PLI
Dumpsite (Ave)	2.63	272.76	0.45	9.81×10^{-2}	1.07	1.37
Farmland (Ave)	1.40	142.22	0.24	2.3×10^{-2}	0.84	1.30
Average Value for Dumpsite and Farmland	2.01	207.19	0.35	6.1×10^{-2}	0.95	1.33
Control site (Ave)	0.66	125	0.11	2.3×10^{-2}	0.46	1.11

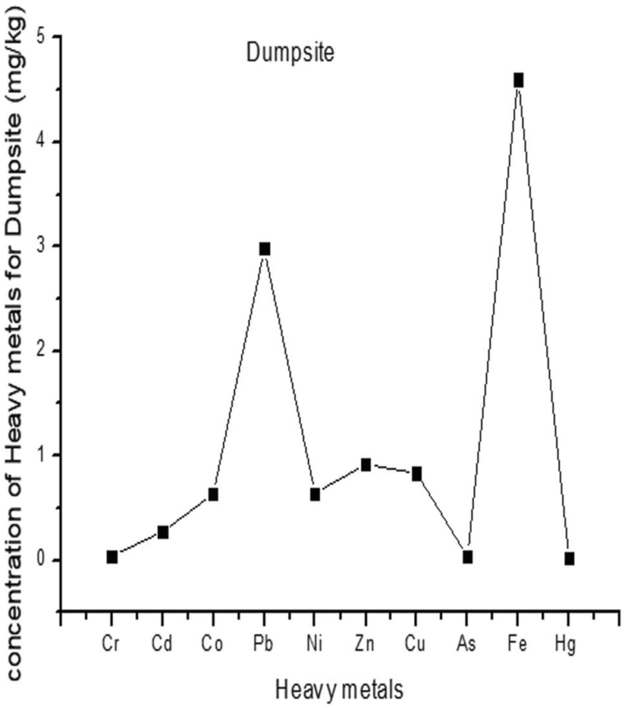

Fig. 3 Ave. concentration of Heavy metals at the Dumpsites

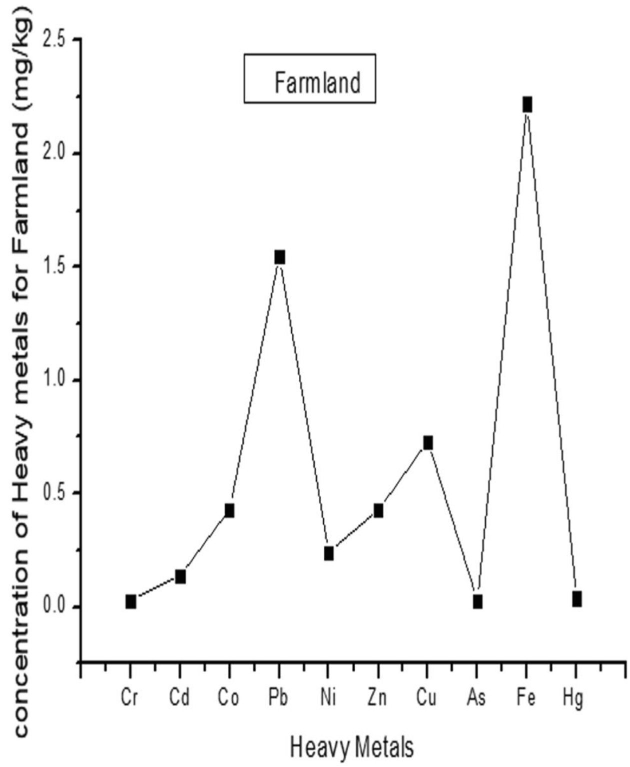

Fig. 4 Ave. concentration of Heavy metals at the Farmlands

4 Results and Discussion

The average value of I_{geo} for soil samples obtained from the dumpsite, surrounding farmlands and the control site were found to be 2.63, 1.40, and 0.66 respectively (Table 6). This showed that the I_{geo} was highest at the dumpsite. Considering that the I_{geo} of the dumpsite was $2 \leq I_{geo} \leq 3$ (Moderately contaminated) farmland gave $1 \leq I_{geo} \leq 2$ (Moderately contaminated to uncontaminated) while the control site gave $0 \leq I_{geo} \leq 1$(Uncontaminated).

The results obtained for Potential ecological risk coefficient (RI) / Ecological risk index (RI) showed that the dumpsite, surrounding farmlands and the control site gave RI values of 272.76, 142.22, 125.00 respectively, from Table 2, the dumpsite gave Moderate Ecological risk level while the farmland and the control site gave low ecological risk level (Figs. 3, 4 and 5).

The Chronic daily intake (CDI) of heavy metals for adults obtained for the dumpsite, surrounding farmlands and the control site gave 0.45 mg/kg/day, 0.25 mg/kg/day, and 0.11 mg/kg/day respectively as displayed in Table 6.

Total carcinogenic risk index (TCRI) gives a more detailed estimate of the potential toxicity of the individual heavy metal in an ecosystem. This study revealed that the dumpsite, surrounding farmlands and the control site have average TCRI values of 9.8×10^{-2}, 2.3×10^{-2} and 2.3×10^{-2} respectively as displayed in Table 6. Considering that TCRI values were below 5 (Kamunda and Madhuku 2016; Zhang et al. 2016). This suggest there is no extreme risk.

Pollution load index (PLI) measures heavy metal pollution or contamination of a site or a location. This study revealed the PLI for the dumpsite, surrounding farmlands

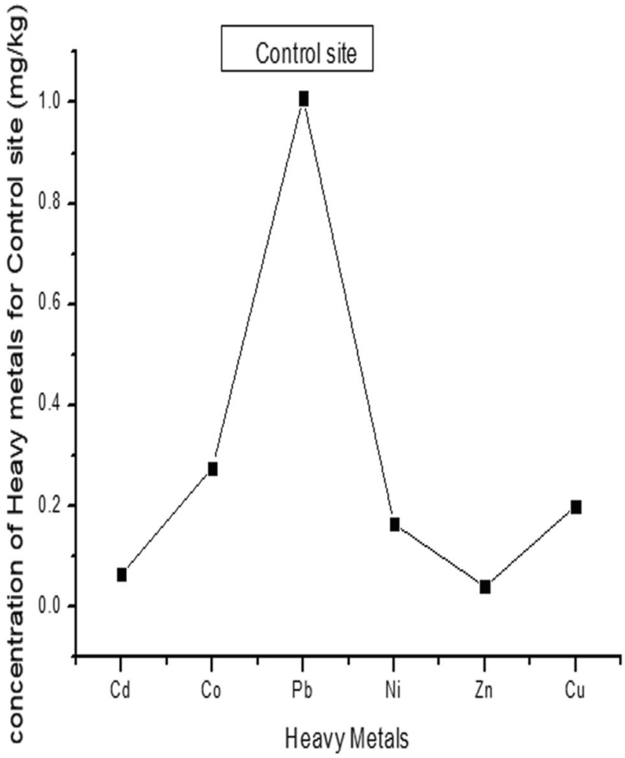

Fig. 5 Ave. concentration of Heavy metals at the Control sites

and the control site were 1.37, 1.30, and 1.11 respectively which indicated low level pollution of the study area at that moment. Contamination level is categorized based on intensities from a scale ranging from 1 to 6 (0 = none, 1 = none to medium, 2 = moderate, 3 = moderately to strong, 4 = strongly polluted, 5 = strong to very strong, 6 = very strong) (Sultana et al. 2017). In this study, the PLI greater than 1 implies heavy metal pollution exists in the medium scale while a value less than 1 implies no heavy metal pollution. The control site has PLI of 1.11 this may be due to residual heavy metals associated to the geological formation of the location.

5 Conclusion

The Average heavy metals concentration of in soil samples from the dumpsites, surrounding farms and control site were evaluated with atomic absorption spectrophotometer (AAS). The heavy metal contamination analysis revealed that average heavy metal concentration of the dumpsites and surrounding farms for Cr, Cd, Co Pb, Ni, Zn, Cu, As, Fe, and Hg were found to be 0.035, 0.21, 0.53, 2.265, 0.44, 0.675, 0.78, 0.035, 3.41, 0.03 mg/kg (dry wt) respectively. The concentration of heavy metals in the studied samples slopes from Pb > Fe > Cu > Zn > Co > Ni > Cd > Cr > Hg > As. Soil contamination was assessed based on geo-accumulation index (I_{geo}), Potential ecological risk coefficient (RI), Chronic daily take (CDI), Total carcinogenic risk index (TCRI), Total hazard quotient (THQ) and pollution load index (PLI). The average values of I_{geo}, CDI, TCRI, THQ and PLI for dumpsites and surrounding farms were found to be 2.01, 207.19, 6.1×10^{-2}, 2.66, 0.95 and 1.33 respectively. Generally, elevated concentrations of heavy metals especially Pb and Fe were observed in the dumpsites and surrounding farmlands. Heavy metal concentration assessment showed slightly elevated but moderate concentration which may pose carcinogenic risk to workers and residents in the surrounding communities. In order to eliminate or mitigate the impact of heavy metal contamination in the studied dumpsites and farmlands, as well as other similar sites the following procedure should be adopted and employed:

a. The introduction of Hyperaccumulator plants like sunflower, mustard, and Indian mustard with the ability to absorb accumulated heavy metals like lead, cadmium, and arsenic from the soil through phytoremediation.
b. The utilization of microorganisms such as bacteria and fungi to degrade or transform heavy metals into less toxic forms through the process of bioremediation.
c. The addition of chemical substances like lime, phosphates, charcoal or biochar to the contaminated soil to immobilize heavy metals. This process minimize the bioavailability of these heavy metals and curtails their probability in entering the food chain.

Finally, the study suggests constant monitoring of heavy metal contamination of the dumpsite and surrounding farmlands to forestall environmental hazard to the surrounding population.

Author Contributions E.O. Echeweozo: Conceived the research idea and designed the calculations. Data curation and analysis—review and editing—Investigation, Methodology, Supervision, Validation, Visualization. Revised and edited the manuscript to be in its final form. P.O Ike: Wrote the original manuscript; revised and edited the manuscript to be in the final form. Data curation and analysis. Two authors have read and approved the final manuscript.

Data Availability No datasets were generated or analysed during the current study.

Declarations

Conflicts of Interest Authors declare that they have no known conflicting interests or personal relationships that could have appeared to influence the work reported in this paper.

Competing Interests The authors declare no competing interests.

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