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RESEARCH ARTICLE

Concentration levels and pollution status of selected heavy metals in active dumpsites in Port Harcourt, Rivers State, Nigeria

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Abstract: This study was carried out to assess the extent of concentration exposure of As, Cu, Cr, Ni and Mn in the soils of five active dumpsites located at (Eliozu, Oyibo, Eneka, Eleme and Woji) in the city of Port Harcourt Rivers State, Nigeria to evaluate the pollution indices of heavy metals. Soil samples were collected randomly at the quadrant from the dumpsite while control samples were collected from farmland 25 km away from the dumpsite. Some physiochemical parameters (pH, TOC and CEC) of the soils were evaluated using standard techniques, while the heavy metal concentrations were evaluated using Atomic Absorption Spectroscopy (AAS). The pollution levels of soil heavy metals were assessed using several pollution indices. The mean concentration of heavy metals (mg/kg) ranged between As (ND – 0.45), Cr (ND – 2.21), Cu (6.05 – 51.87), Mn (3.24 – 37.91), Ni (ND – 13.50) across the studied dumpsites. The heavy metal levels in soil samples observed were in the order of Cu > Mn > Ni > Cr > As (Eleme), Cu > Mn > As > Ni > Cr (Eliozu), Cu > Mn > Ni > Cr > As (Eneka), Cu > Mn > Cr (Oyigbo), Cu > Mn > Ni > Cr > As (Woji), Cu > Mn > Ni > Cr > As (Control Site). The pH results were relatively acidic across the studied dumpsites ranging from 5.7± 0.58 to 6.63± 0.02, while the TOC levels were low to moderate showing no wide disparity in the values. The Cation exchange capacity (CEC) showed a range of 13.98±0.186 (Eneka) to 20.98±0.061 cmol/kg (Woji) across the studied dumpsites. The Igeo values except for Ni, Cu and Mn at Eneka dumpsite, Cr and As in all the studied dumpsites revealed moderate to heavy contamination. Pollution load index (> 1) was in the studied dumpsites which implies that there is heavy metal pollution across the studied dumpsites. Anthropogenicity indicates that human activity is mostly responsible for the increase in metals in the studied area. Low ecological risk indices for the heavy metals (Ni, Cu, Cr, Mn, As) were found in all the sampling locations except for copper in Oyibo dumpsite. According to the findings, there is a low to moderate level of heavy metal pollution in the soils from the dumpsite, which can deteriorate the food ecosystem if adequate measures are not put in place.

Keywords: dumpsite, ecological risk, heavy metals, pollution indices

1 Introduction

Both man-made and natural processes release heavy metals into the ecosystem, which end up in various environmental media [1]. Geological weathering of soils and rocks is the most important natural source of heavy metals [2] while anthropogenic sources include municipal wastes, sewage sludge, medical wastes, fertilizers, pesticides, herbicides, mining, the use of batteries, paints and metal scraps [3,4]. Heavy metals are known to be toxic as they destabilize the ecosystem, bioaccumulate and speciate in both flora and fauna in tandem with humans across different food chains thus leading to immerse public health issues from short and long-term exposure [5]. Due to inadequate waste management strategies, the number of open dumpsites in Port Harcourt metropolis has expanded along with the city's population and level of civilization. Burning rubbish from landfills is a popular procedure that removes organic matter and produces ashes with a higher metal content. Either these ashes dissolve in rainwater and seep into the earth, contaminating subterranean water, or runoff carries them away into streams and rivers, polluting the surrounding waterways [1,6,7].

Either alone or in conjunction with other elements of the soil, heavy metals can be found. These elements might consist of exchangeable ions that have been sorbed onto the surfaces of inorganic solids, non-exchangeable ions and insoluble inorganic metal compounds [8]. Due to the complexicity of diverse materials that find their entry into the soil system, they tend to interact, persist, magnify and accumulate to toxic levels leading to serious ecological and health impacts to organisms [9, 10]. Many factors, including the parent rock, climate, and human activity, can affect the level of heavy metals in soil and their effects on ecosystems. These factors can also lower crop output and quality, which can affect human health through the food chain and result in deteriorating air and water quality [11, 12]. Heavy metals are naturally occurring components of soil, acting as a sink for pollutants.

However, they are classified as contaminants when their concentrations have been surpassed, they are widely present, and they induce both acute and chronic toxicity [13]. Natural terrestrial and aquatic ecosystems have been disrupted by the presence of excess amounts of certain heavy metals in soil, such as Cr^{6+}, Cu^{2+}, Ni^{2+}, and Zn^{2+} [14]. Numerous studies have been conducted on the detrimental effects of heavy metals produced by solid waste dumpsites on aquatic life, humans, and the ecosystem as a whole [1, 5, 15]. It's critical to periodically assess the pollution situation at Nigeria's operational dumpsites to supply statistical data that could assist public health professionals and the government in formulating, enforcing, and regulating policies. The objective of this study is to ascertain the levels of concentration and contamination status of specific heavy metals in a subset of active trash dumpsites located in Port Harcourt, in the Niger Delta region of Nigeria.

2 Materials and Methods

2.1 Study area description

The study area consists of (5) active dumpsites located in Port Harcourt Rivers State Nigeria. The dumpsites selected were located at Eneka (04054'16.4′′N, 006055'8.6′′E) (Figure 1), Oyigbo (04053'07.4′′N, 007000'50.1′′E) (Figure 2), Eliozu (04°53'34.1′′N, 006054'48.7′′E) (Figure 3), Eleme (4.7994°N (Figure 4), 7.1198°E) and Woji (4.8283°N (Figure 5), 7.0579°E). Residential buildings, factories, gas stations, an auto parts store, and vehicle repair businesses are all located close to the dumpsites. Residents, rag-pickers, and bystanders, especially young children, are exposed to toxins in the soil and water through ingestion, inhalation, and skin contact. The research area has two distinct seasons: the tropical dry season, which runs from November - February, and the tropical wet season, which runs from March - October. The mean annual rainfall increases from 2000 mm at the northern border to approximately 4500 mm near the coastal margin [16].

Figure 1 Eneka dumpsite (Latitude: 4°53'34.1′′N, Longitude: 6°54'48.7′′E)

Figure 2 Oyigbo dumpsite (Latitude: 4°53'7.4′′N, Longitude: 7°00'50.1′′E)

Figure 3 Eliozu dumpsite (Latitude: 4°54'16.4"N, Longitude: 07°11'98"°E)

Figure 4 Eleme dumpsite (Latitude: 04°79'94"N, Longitude: 06°54'48.7′′E)

Figure 5 Woji dumpsite (Latitude: 04°82'83"N, Longitude: 07°05'79"E)

2.2 Sample collection

Using a soil auger and a spatula, soil samples were haphazardly taken from the dumpsite at a depth of 0 to 15 cm after the trash above was removed. There were four quadrants created for each dumpsite. Four soil samples were taken from each quadrant's sampling points, which ranged in length from 10 to 30 meters (East, West, South, and North). The samples were homogenized to form a composite sample. Samples of soil were taken at the control sites, which are farmlands with little human activity, 200 meters away from the dumpsite. The samples of composite soil were allowed to air dry for 48 hours at room temperature. After that, the surface area was reduced by grinding them with a porcelain pestle and mortar, and the fine earth fraction was obtained by sieving them through a 2-mm nylon mesh. These were brought to the laboratory for additional analysis after being labelled and stored in tight polythene bags.

2.3 Determination of soil physicochemical properties

The parameters determined were pH, Total organic carbon (TOC) and cation exchange capacity (CEC). A soil-to-distilled water ratio of 1:1 was used to calculate the pH of the soil sample. Ten grams of the soil sample weighed from each dumpsite, were combined with 10 mm of distilled water and thoroughly mixed. The mixture was then let to stand for thirty minutes. A stable reading was obtained after rinsing the pH meter electrode with distilled water and inserting it into the sample solution [17]. To obtain an average pH value, triplicate pH readings were obtained. TOC was done using the west combustion method described by Walkey and blacky [18] while CEC was done using the ammonium acetate method described by Stewart [19]. Analytical grade reagents purchased from Sigma-Aldrich were used for the study.

2.4 Heavy metal assessment of soil samples

Analytical grade reagents purchased from Sigma-Aldrich were used for the study. Using a digital weighing balance, 2 gm of the dried and sieved soil samples were put into a 125 mL beaker. 30 mL of (65% HNO_3 and 35% HCl) were used to digest the soil samples for 3 hours at 45°C on a hot plate. To lessen the influence of biological materials, these were carried out. After letting the digested samples settle to ambient temperature, they were filtered through Whatman filter paper into a 100 mL volumetric flask. Deionized water that had been diluted to a 25 mL volume was used to wash the beaker sides. The sample was moved into the proper test tube [17]. To evaluate the levels of As, Cr, Cu, Mn and Ni, the digested soil was fed into an AAS (Model: Varian AA240FS). For each sample, three duplicate determinations were made.

2.5 Pollution index models

The under-listed contamination indices were adopted to evaluate the level of contamination of the soil samples collected from selected active dumpsites around Port Harcourt.

2.6 Contamination Factor (CF)

The waste dumpsites' level of contamination was assessed using the CF formula [20].

$$CF = \frac{Cn}{Bn} \quad (1)$$

where Cn is the amount of heavy metals present in the dump locations under study, and Bn is the background concentration at the control site; which are As = 0.001, Cu = 6.05, Ni = 2.803, Mn = 4.32, Cr = 2.07. It is suggested that the CF be divided into the following categories: Low contamination (CF $<$ 1), moderate contamination (1 $\leq$ CF $<$ 3), considerable contamination (3 $\leq$ CF $<$ 6) CF $\geq$ 6, and very high contamination [21].

2.7 Pollution Load Index (PLI)

The primary purpose of the pollution load index is to evaluate the state of the environment [22]. This is obtained by using Tomlinson *et al.* [23] method as shown in the equation below.

$$PLI = (CF_1 \times CF_2 \times CF_3 \cdots CF_n)^{1/n} \quad (2)$$

For each heavy metal under study, n is the number of heavy metals, and CF is its contamination factor. If PLI $>$ 1, then there is heavy metal pollution; if PLI $<$ 1, then there is no heavy metal pollution [23].

2.8 Index of Geo-accumulation

One common tool for assessing the level of heavy metal pollution in the environment is the Igeo [24]. It also refers to the extent of damage done by this contaminant to the environment. Igeo is expressed mathematically [25] as shown in the equation;

$$Igeo = log_2(\frac{Cn}{1.5Bn}) \quad (3)$$

In this case, Bn represents the background or control concentration of a particular metal, Cn is the concentration of the heavy metal in the dumpsites under study, and 1.5 is a factor that justifies any fluctuations in the background or control concentration caused by lithologic variances. The Igeo is categorized into seven descriptive classes as follows: $\leq$ 0, practically uncontaminated (class 0); 0-1, uncontaminated to slightly contaminated (class 1); 2-3, moderately to highly contaminated (class 2); 4-5, highly to very strongly contaminate (class 3); and $\geq$ 5, extremely contaminated (class 4) [24, 25].

2.9 Anthropogenicity (Apn %)

The percentage measure of anthropogenicity, or Apn%, quantifies the direct impact of humans on metal concentrations [26]. The following formula is used to compute it:

$$APn\% = \frac{\mu}{Cn} \quad (4)$$

where Cn is the background value and μ is the measured concentration. The world average shale values in mg/kg that were taken from Edori and Kpee serve as the baseline values for the anthropogenicity computation [27]. The values are As = 13, Cr = 90, Cu = 45, Ni = 68 and Mn = 850.

2.10 Potential ecological risk index

By utilizing the toxicity of heavy metals and their environmental response factor, as demonstrated by Hakanson, the assessment of possible ecological risk aims to determine the extent of heavy metal pollution in soils [20]. The potential ecological risk was evaluated using the formula [28].

$$Eri = Tri\ x\ CF \quad (5)$$

$$RI = Z\ Eri \quad (6)$$

According to Hakanson [20] and Hussain et al. [22], the values for each element are Ni = 5, Mn = 1, Cu = 5, As = 10, and Cr =2 . Eri is the potential ecological risk factor, CF is the contamination factor, and Tri is the metal toxic response factor. The possible ecological danger index related to the overall heavy metal contamination under study is represented by RI. According to Hakanson [20], the prospective ecological risk factor (Eri) and potential ecological risk index are divided into the following five categories; *Eri* $<$ 40 is at low risk, 40 $\leq$ *Eri* $<$ 80 is at moderate risk, 80 $\leq$ *Eri* $<$ 160 is at considerable risk, 160 $\leq$ *Eir* $<$ 320 is at high risk and 320 $\leq$ *Eri* is at very high risk. RI $<$ 110 is at low risk, 110 $\leq$ RI $<$ 200 is at moderate risk, 200 $\leq$ RI $<$ 400 is at considerable risk and 400 $\leq$ RI is at very high risk.

2.11 Statistical evaluation

Microsoft Excel 2016 and the SPSS software version 20.0 were used to analyze data from soil samples.

3 Results and discussion

3.1 Physicochemical parameters of soil dumpsites

Table 1 shows the mean level of pH, TOC and CEC identified in the soil samples. The results indicate that pH values were observed to be relatively acidic for different waste dumpsite, ranging from 5.7± 0.58 to 6.63± 0.02. Eneka dumpsite was the highest, while Woji dumpsite was the least. One of the key elements influencing the mobility, retention, and availability of heavy metals and nutrients in soils is pH [7]. According to assessments, the organic content of the soil from waste dump sites contributes significantly to the mobility factor from decomposing organic matter that produces hydrogen ions (H+), which in turn influences the pH of environmental matrices. This is because organic matter has a metallic ion complexion as a result of biological activity and agrochemical reactions [29]. Compared to alkaline soils, low pH levels of metals can lead to serious toxicity issues since they are more bioavailable to plants. Reduced pH levels also affect high reactivity, dissolve, and subsequently release pollutants into the water supply across a large area, affecting the water's colour, taste, and aesthetic quality [1, 30]. The pH results from this study are similar to that reported by Amos- Tautua *et al.* [31], and Oviasogie *et al.* [32]. TOC of soils determines the sorption capacity of the soil organic molecules for heavy metals [33]. There is no wide disparity in the values of the percentage TOC of the soil. TOC in the soils was low to moderate ranging from 0.88± 0.0021% (Eliozu) to 2.56± 0.021% (Eleme) as shown in Table 1. The moderate amount of % TOC of the waste dumpsite soils indicates the presence of degradable wastes [34], signifying that soil samples in all the studied dumpsites contain almost the same proportion of organic matter in them. The CEC of the dumpsite soils ranged from 13.98±0.186 (Eneka) to 20.98±0.061 cmol/kg (Woji). The CEC range reported is higher than 3.27-13.25 cmol/kg obtained by Oviasogie *et al.* [32], but lower than 61.08±0.09 - 91.07±0.11 cmol kg reported by Amos-Tauta et al. [31] in waste dumpsite soils. The mean results of CEC obtained from the study are higher than the values reported in the control site, thus indicating that waste dumpsite has higher nutrient storage capacity, therefore, waste dumpsites soils are more fertile than to control site. The CEC of soil is an important indicator of soil fertility because it shows the ability of the soil to provide active sites for cation exchange and release elements and compounds, which depends particularly on the pH, clay content and soil organic matter content [34, 35]. The CEC of the dumpsite soils was within 20 cmol/kg which favours crop production [36].

Table 1 Physicochemical parameters of Dumpsite soil samples

Dumpsite locations	pH	CEC (cmol/kg)	TOC (%)
Eliozu	5.85±0.01	19.37±0.18	0.88±0.02
Eneka	6.63±0.02	13.98±0.19	1.17±0.03
Oyibo	6.39±0.02	20.76±0.10	1.64±0.02
Woji	5.70±0.58	20.98±0.06	1.18±0.02
Eleme	5.91±0.02	15.72±0.55	2.56±0.02
Control site	5.69±0.02	12.59±0.22	0.96±0.02

3.2 Heavy metal concentration of soil dumpsites

Figure 6 shows the mean level of heavy metals identified from different soil waste dumpsites and control sites. Arsenic (As) was present in Eleme, Eliozu, Eneka and Woji ranging between 0.12 – 0.45 (mg/kg), which can be attributed to proximity to industrial waste and artesian waste from auto-mechanicals technicians. Chromium (Cr) were detected across all sample sites, as it's mainly due to anthropogenic releases from automobiles, lead-chromium batteries, metal leaching and corrosion that are readily dissolved and leached soil and water sources accordingly [1]. Copper and Manganese were present across all sample sources, which is dependent on acid pH level that leads to immersed leaching of metal sources across anthropogenic sources into diverse environmental sources (water and soil) [37]. Nickel was absent in Oyigbo, which could be due to proximity to source pollutants, as nickel is mainly released from petrochemical, oil and gas and industrial waste deposition of nickel [38].

3.3 Geo accumulation index (Igeo)

The Igeo was used to explain the nature of the soil dumpsites and the values are shown in Table 2. Igeo values indicated that the studied dumpsite soils were not contaminated by Cu, Cr and Ni at Eneka dumpsite and As at Eliozu dumpsite (Igeo < 0), uncontaminated to moderately

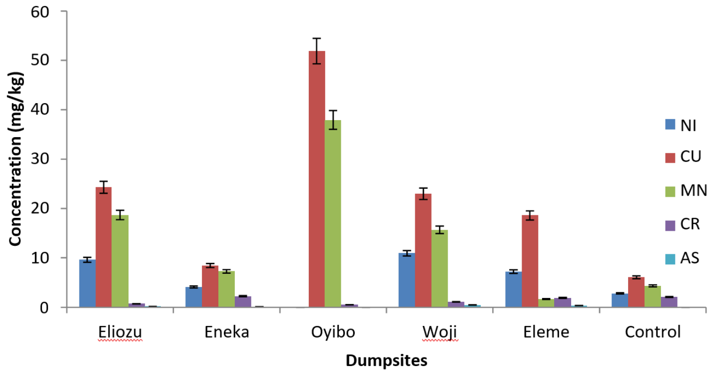

Figure 6 Heavy metal concentrations in the study area soils

contaminated‖ by Ni, Mn and As in Eleme and Eneka dumpsites respectively (Igeo < 1), and moderately contaminated by As in Woji and Eleme dumpsites; Ni in Eliozu and Woji dumpsite; Cu and Mn in Eliozu, woji and Eleme dumpsites (Igeo < 2), moderately to heavily contaminated by Cu and Mn in Oyibo dumpsite. The average Igeo values were ordered as: Mn > Cr > Cu > Ni > As. The results show that the Igeo of the heavy metals is in the order Mn > Cr > Cu > Ni > As. The Igeo values except for Ni, Cu and Mn at Eneka dumpsite, Cr and As in all the studied dumpsites suggest moderate to heavy contamination. Mn accounted for the highest Igeo (2.55) at Oyibo dumpsite which corresponds to its highest contamination factor at this same matrix. Additionally, the mean value of Igeo of metals in the matrices showed that Eneka dumpsite was practically uncontaminated with a value of -0.16 while Eliozu, Oyibo, Woji and Eleme dumpsites were moderately polluted with values 0.34, 0.79, 0.81 and 0.84 respectively. Increasing anthropogenic activities cause increased geo- accumulation of these metals in the soil that are known carcinogenic and mutagenic to flora and faunas, when in extreme concentrations thereby impacting the natural manageable level that is assimilated to prevent adverse ecological impact [39].

Table 2 Mean Igeo values of soil at the different dumpsites

Dumpsites/Locations	Ni	Cu	Mn	Cr	As	Mean	Igeo values
Eliozu	1.19	1.42	1.53	-2.16	-0.01	0.34	0-Uncontaminated
Eneka	-0.03	-0.11	0.16	-0.49	-0.32	-0.16	0-1 uncontaminated to moderately Contaminated
Oyibo	-	2.51	2.55	-2.69	-	0.79	1-2 Moderately contaminated
Woji	1.38	1.34	1.28	-1.52	1.58	0.81	2-3 moderately to heavily Contaminated
Eleme	0.78	1.03	1.97	-0.73	1.14	0.84	3-4 Heavily contaminated
Mean	1.0	1.37	1.62	1.52	0.51	-	4-5 Heavily to extremely contaminated
Maximum	1.38	2.51	2.55	-2.69	1.58	-	$\geq$ 5 Extremely contaminated
Minimum	-0.03	-0.11	0.16	-0.49	-0.01	-	

3.4 Contamination Factor (CF)/ Pollution Load Index (PLI)

The result presented in Table 3 and Figure 7 reveals the CF and PLI of analyzed metals in soils from the studied dumpsites respectively. CF ranged from 0.33-4.32, 1.07 – 1.68, ND-8.78, 0.52- 4.50, 0.38- 3.30 in Eliozu, Eneka, Oyibo, Woji and Eleme dumpsites respectively. Mn had the highest CF (8.78) in Oyibo dumpsite while Cr was recorded lowest CF (0.23) in Oyibo dumpsite. The mean CF of all the studied metals were greater than 3, indicating considerable contamination except As and Cr which had moderate contamination. Average CF values for all metals were ordered as follows; Cu > Mn > Ni > As > Cr (Table 3). The high metal contamination of Cu and Mn in Oyibo dumpsite could have resulted from emissions from industries close to the study areas as well as copper and Manganese- containing waste that is being received by the different dumpsites. Therefore, from the study, contamination factor results show that the soil across the waste dumpsites is considerably contaminated by Ni, Cu, Mn and As. Oyibo dumpsite is highly contaminated with Mn (8.78) and Cu (8.57) while Eliozu and Woji dumpsites are moderately contaminated with Ni showing high values of 3.43 and 3.89 respectively.

The PLI (> 1) was in all the studied dumpsites with values of 1.94, 1.34, 1.77, 2.63, and 1.55 for Eliozu, Eneka, Oyibo, Woji and Eleme dumpsites respectively, which implies heavy metal pollution across the studied dumpsites. The PLI and CF observed in this study are harmonious with other studies [40–42].

Table 3 CF of heavy metals in the studied dumpsite soils

Dumpsites	Ni	Cu	Mn	Cr	As
Eliozu	3.43	4.01	4.32	0.33	1.40
Eneka	1.46	1.39	1.68	1.07	1.20
Oyibo	-	8.57	8.78	0.23	-
Woji	3.89	3.79	3.63	0.52	4.50
Eleme	2.57	3.07	0.38	0.90	3.30
Mean	2.27	4.17	3.76	0.61	2.08
Maximum	3.89	8.57	8.78	1.07	4.50
Minimum	1.46	1.39	0.38	0.23	1.20

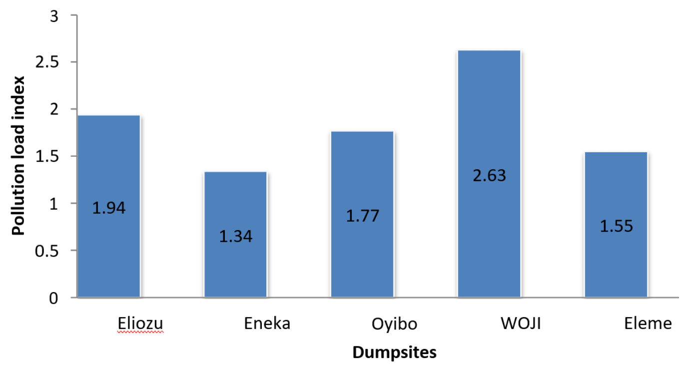

Figure 7 Pollution load index of the studied dumpsites

3.5 Anthropogenicity (APn%)

Anthropogenicity was used to measure the % or extent of anthropogenic input on the dumpsite soil as revealed in Table 4. Cu had a high anthropogenic input for dumpsite located at Oyigbo, Eliozu, Woji and Eleme with a very high anthropogenic input (115%) at Oyigbo dumpsite. No anthropogenic input was observed for As and Ni at Oyigbo dumpsite. The mean value of anthropogenicity for all metals across the studied dumpsite followed the decreasing order Cu > Ni > As > Cr > Mn, Cu > Ni > Mn > As > Cr, Cu > Ni > Cr > As > Mn, Cu > Mn > Cr > As > Mn, Cu > Ni > As > Mn > Cr and Cu > Ni > Cr > Mn > As for Eleme, Eliozu, Eneka, Oyigbo, Woji and control. Copper, nickel and chromium are usual metals that are linked with activities done at industries, mechanic workshops and disposal of spent chemical cans [26]. Consequently, to reduce the % of these metals' impact on the soil, the area's activities must be regulated.

Table 4 Anthropogenicity (APn%) of soil from different dumpsite samples

Sampling points	As	Cr	Cu	Mn	Ni
Eleme	2.54	2.07	41.27	0.194	10.58
Eliozu	1.07	0.76	53.95	2.197	14.12
Eneka	0.923	2.45	1.871	0.853	6.03
Oyigbo	0.0	0.53	115.27	4.46	0.00
Woji	3.46	0.012	51.06	1.845	16.03
Control	0.0	2.3	13.44	0.51	4.12

3.6 Potential Ecological Risk (Eri) assessment

Table 5 reveals the Eri assessment of heavy metals from active dumpsites. The Eri values ranged from low risk (Eri < 40) to moderate risk (Eri $40 \leq$ Eri < 80). Soil samples from both studied dumpsites indicated low Eri for the heavy metals (Ni, Cu, Cr, Mn and As) except for Cu in Oyibo dumpsite. Furthermore, the ecological risk showed low risk (Eri < 150). The concentration of copper in Oyibo dumpsite is high, which shows the effect of human activities [43].

To prevent additional harm to the ecosystem and food chain, ecological risk assessment is crucial for identifying potential threats and dangers posed by heavy metals to the environment. It has been observed that these hazardous heavy metals can have a variety of detrimental impacts on biological systems when exposed to them continuously through diverse pathways [44–50].

Table 5 ERI evaluation results of heavy metals from the dumpsite soil

Dumpsites	Ni	Cu	Mn	Cr	As	Risk Index
Eliozu	17.5	20.5	4.32	0.66	14.0	56.63
Eneka	7.3	6.95	1.68	2.14	13.4	31.47
Oyibo	5.0	42.85	8.78	0.46	10.0	67.09
Woji	19.45	18.95	3.63	1.04	45.0	88.07
Eleme	12.85	15.35	0.38	1.8	33.0	63.38

4 Conclusion

Heavy metal contamination levels and possible risks were evaluated in the soil of a dumpsite in the study area. The mean level of heavy metals (mg/kg) ranged between ND – 0.45, ND – 2.21, 6.05 – 51.87, 3.24 – 37.91, and ND – 13.50 for As, Cr, Cu, Mn, and Ni respectively among the examined dumpsites and were greater than control samples. Use of the CF, PI, Igeo, and Eri shows unequivocally that all of the soil samples from the dumpsite were classified as having low to moderate levels of contamination and that heavy metals may pose potential ecological risk. Though the pollution level of the soil within the dumpsites was not severe nevertheless stringent measures should be developed and improved to control waste disposal in these dumpsites since heavy metals can bioaccumulate, and bio-magnify in the soil.

Conflict of interests

The authors declare no conflict of interest.

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