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Heavy Metal Contamination of Ewhare Dumpsite Environment in Nigeria's Niger Delta.

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ABSTRACT

This study characterized some indices of heavy metals in the soils of Ewhare dumpsite and adjoining land in Agbaro-Warri, Delta State, in Nigeria's Niger Delta in order to ascertain the status and degree of contamination there. Six soil samples were collected within the dumpsite or down slope location (DS) and the adjoining up slope location bordering the dumpsite (US) at three depths. Samples collected were pre-treated and analyzed using standard procedures and necessary precautionary quality assurance steps observed. The heavy metal composition was determined in Atomic Absorption Spectrophotometer. The result showed that the concentration of heavy metal were in the following decreasing order: Fe > Zn > Mn > Cu > Pb > Cd > Cr > Ni > V. Computation of Enrichment factor (EF) of the heavy metals showed that there was a,moderate enrichment for copper (Cu), a significant enrichment of zinc (Zn) and nickel (Ni), very high enrichment for chromium (Cr), cadmium (Cd), lead (Pb) and vanadium (V). The Contamination factor (CF) indicated low contamination of Fe, moderate contamination of manganese (Mn), copper (Cu) at the dumpsite location and only the top soil (0-15cm) of the adjoining land; considerable contamination of nickel (Ni) and vanadium (V) at the dumpsite and top soil of the adjoining land; very high contamination of zinc (Zn), chromium (Cr), cadmium (Cd), and lead (Pb). Pollution Load Index (PLI) showed that Ewhare dumpsite is polluted (PLI > 1) by metals. The Geo accumulation Index (Igeo) showed that soils of Ewhare dumpsite was practically not polluted for Fe and Mn from anthropogenic standpoint. However, it is moderately to heavily polluted with zinc (Zn) and nickel (Ni); heavily polluted with vanadium (V); heavily to extremely polluted with chromium (Cr), cadmium (Cd), and lead (Pb). Potential ecological risk index (PERI) showed slight pollution of manganese (Mn), zinc (Zn) and copper (Cu), medium pollution for chromium (Cr), Strong pollution for nickel (Ni); very strong pollution for lead (Pb) and extremely strong pollution of cadmium (Cd). The risk index (RI) for Ewhare dumpsite indicated a very strong risk or level D for the dumpsite and adjoining upslope location respectively. Mn, Zn, CU, Cr, Pb and Ni showed low ecological risk (RI < 150) in all sample depths in the study area except Cd which showed very high ecological risk (RI> 600) in all sample depths in the study area. In view of the level of soil pollution of this dumpsite located in an estuarine setting, with shallow aquifer, it is suggested that an alternative be sought for this dumpsite as there is a high probability of groundwater contamination with heavy metals which could endanger the health of local inhabitants that depend on water wells for their domestic use. If the dumpsite must remain opened on the short-term, it is suggested that soil and groundwater monitoring program be initiated by the State Environmental Ministry and appropriate warnings disseminated when necessary. Furthermore, comprehensive studies of organic contaminants in the dumpsite soil and it's environ is also recommended in view of the sundry wastes dumped daily.

Keywords: HeavyMetals, Municipal solid Waste dumpsite, Soil pollution, Warri, Pollution index

Introduction

The soil from antiquity has been the primary repository of all wastes (Adedosu *et al.,* 2013). Millions of tons of toxic solid wastes from a variety of sources annually find their way into dumpsites. Pollutants from these wastes most often penetrate the lower soil horizons and subsequently polluting the ground water at varying degrees. The presence of heavy metals in the environment beyond acceptable limits calls for concern because of the deleterious effects of toxic metals on humans, animals and plants (Caylak and Tokar, 2012). Exposure to toxic heavy metals like lead and cadmium have been reported to cause blood and bone disorders, kidney damage, decreased mental capacity and neurological damage (Esakku, *et al*., 2003; Yurtsever and Sengil, 2009).

Municipal and industrial solid wastes contain a variety of potentially significant chemical constituents and pathogenic organisms that could negatively affect public health, air, soil and groundwater qualities. These constituents include regulated hazardous priority pollutants such as heavy metals, polyaromatic hydrocarbons (PAHs), polychlorinated biphenyls (PCBs) and other persistent organic pollutants (POPs) (Ikem, *et al*., 2002; Osibanjo, 2003; Anetor, *et al*., 2008).

Disposal of solid wastes in major cities of Nigeria in the last few decades has posed major environmental and public health problems. This has become a source of worry for rural and urban planners in Nigeria because of the explosive population growth and urbanization. Several studies have implicated high heavy metals levels in leachate and soils within the vicinity of dumpsites (Ogundiran and Afolabi, 2008; Oyelola and Babatunde, 2008). Consequently, there is need to simultaneously and regularly assess the levels of some toxic heavy metals in soil, leachates and underground water samples from the vicinities of the waste dumpsites.

Warri metropolis is located between latitude 5˚30'N and 5˚35'N and Longitude 5˚29'E and 5˚48'E. Warri has grown to cover the surrounding towns of Effurun, Ekpan, Enerhen, Edjeba, Ogunu, Jakpa, Ovwian-Aladja, Udu Road, etc with an aerial expansion of over 100 km^2 (Efe and Ojoh, 2013). This areal expansion has led to increase in temperature and precipitation in the area (Efe *et al.,* 2013). The area is characterized by hydromorphic soils, which is a mixture of coarse alluvial and colluvial deposits; it is also characterized by tropical equatorial climate with mean annual temperature of 32.8˚C and annual rainfall amount of 2673.8 mm. Rainfall period ranges from January-December, with the minimum value of 8.2 mm in January and over 536.6 mm in September. Warri metropolis is one of the rapidly growing cities in Nigeria, with a population rising rapidly from 19,526 in 1933, to 280,000 in 1980, 536,023 in 2006. The population growth has led to an increase in the amount of solid waste generated (Efe and Ojoh, 2013).Warri lies within the Niger Delta region underlain by quaternary to recent sedimentary formations. The coastal sands and conglomeratic beds are of good to excellent aquifer characteristics but are predominantly unconfined thus making them vulnerable to surface and subsurface water contaminants especially from such sources as dumpsites. The vulnerability is bound to increase with the tropical heavy rainfall typical of the area (Akudo *et al.,* 2010). This study was therefore initiated with thre primary objective to evaluate the magnitude of heavy metal contamination of Ewhare solid waste dumpsite and its adjoining land using established pollution indexes for heavy metals.

Methodology

Sample Collection: Soil samples were collected at three depths (0-15cm, 16-30cm and 30-45cm) with a hand driven soil auger within the dumpsite or down slope (DS) and the adjoin upland location or upslope (US) of the dumpsite. About 100g of soil sample from each location was taken in each location and placed in labeled Ziploc plastic bags. A hand-held GPS (model e TrexHcSerier Garmin) was used to obtain the geographic coordinates of each sampling location. Samples collected were placed in a cooler and taken to the laboratory for analysis.

Sample preparation: Soil samples collected were air-dried at 25^o C – 27^o C for a period of 72 hours. The samples were crushed and sieved through a 2mm sieve and packed in a well labeled sample cups for laboratory analysis. Soil samples were analyzed for chemical properties using standard procedures. Necessary precautionary quality assurance methods were observed to prevent sample contamination.

Heavy Metal Analysis

Heavy metals were determined in the Laboratory for Ecotoxicology and Environmental Forensics, University of Benin, Benin City. Sample digestion and the determination of the heavy metal concentration in the digested samples were carried out by the method of the Association of Analytical Chemists, (AOAC, 2000). Heavy metal analysis was done using Atomic Absorption Spectrophotometer (AAS Bulk Scientific 210 VGP). The equipment was first calibrated using buck certified atomic absorption standards for the respective heavy metals to obtain calibration curve. Reagent blank was first run at intervals of every ten sample analysis to eliminate equipment drift. All samples were analyzed in duplicates for reproducibility, accurate check and precision.

Assessment Indices

The following quantitative indices were used to assess the heavy metal concentrations in this study:

1. Enrichment Factor

Enrichment factor (EF) was assessed according to Duce (1990) and Simex and Helz (1981). EF was employed to assess the degree of contamination and to understand the distribution of the elements of anthropogenic origin from sites by individual elements in soil. Iron (Fe) was chosen as the normalizing element while determining EF values-as it is one of the widely used reference element (Kothai *et al.,* 2009; Seshan*et al.,* 2010; Odukoya and Abiodun, 2015; and Nweke and Ukpai, (2016). The formula for enrichment factor is stated as:

EF= (X/Fe) soil/(X/Fe) background

Where Ef = Enrichment Factor (unitless)

X= Elemental Concentration

According to Sutherland (2000), five categories are generally recognized on the basis of enrichment factor (EF).

EF < 2: depletion of mineral enrichment or no enrichment

2≤EF<5: moderate enrichment

5≤EF<20: significant enrichment

20≤EF<40: very high enrichment

EF>40: extremely high enrichment

2. Contamination Factor (CF) and Pollution Load Index (PLI)

According to Hakanson (1980), CF values were interpreted as follows:

If CF < 1: low contamination.

1 < CF > 3: moderate contamination.

3 < CF < 6: considerable contamination.

CF > 6: very high contamination.

PLI can be expressed as

$$PLIofastudyarea\ = n\sqrt{C_f^i 1 \times C_f^i 2\times\ C_f^i\ 3\times\ C_f^i \ldots \times C_f^i n} ---$$

For assessing the level of heavy metal pollution, this empirical index provides a simple comparative means.When PLI > 1, means that pollution exist; otherwise; if however,PLI < 1, there is no metal pollution (Tomlinson *et al.,* 1980) .

3. Geo accumulation index (Igeo)

According to Muller, (1969) and Boszkeet *et al.,* (2004), Igeo can be expressed as:

$$Igeo = \log2 \left(C_n / 1.5\ B_n\right)$$

Where:

Cn is the measured concentration of the metal (n) in the sample

Bn is the geochemical background concentration of the metal, n.

Igeo consists of seven classes (0 - 6), indicating various degrees of enrichment above the background values and ranging from unpolluted to very highly polluted as expressed by Muller, (1979) and Boszke*et al.,* (2004)

Class 0 (practically unpolluted): Igeo ≤ 0

Class 1 (unpolluted to moderately polluted): $0<Igeo<1$

Class 2(moderately polluted): $1<Igeo<2$;

Class 3 (moderatelyto heavily polluted): $2<Igeo<3$;

Class 4 (heavily polluted):$3<Igeo<4$;

Class 5 (heavily to extremely polluted):$4<Igeo<5$;

Class 6 (extremely polluted):$5>Igeo$

(Muller 1979, Bhuiyan*et al.,* 2010) in Nweke and Ukpai, (2016)

4. *Potential Ecological Risk Index (PERI)*

The potential ecological risk index (PERI) method of Hakanson, (1980) was used to evaluate heavy metal contamination from the perspective sedimentology reflected in the equation below and was adopted to evaluate the heavy metal pollution in the soils and also to associate ecological and environmental effects with their toxicology and the toxic-response factor T_{ri} of Cu, Zn, Cd, Mn, Fe and Pb. An ecological risk factor (*Er*) is quantitatively expressed as the potential ecological risk of a given contaminant.

$$Er=Tr\cdot Cf$$

Where:

Tr = the toxic-response factor for a given substance

Cf = the contamination factor.

The following terminologies are used to describe the ecological risk factor:

Eri<40low potential ecological risk;

40≤*Eri* <80, moderate potential ecological risk;

80≤*Eri* <160, considerable potential ecological risk;

160≤*Eri* <320, high potential ecological risk; and

Eri≥320, very high ecological risk.

The potential ecological risk index (RI) was in the same manner as degree of contamination defined as the sum of the risk factors:

RI = Σ *Er*

i=1

The following terminologies are used for the potential ecological risk index as given by Hakanson (1980):

RI<150, low ecological risk;

150≤RI<300, moderate ecological risk; and

RI>600, very high ecological risk

Table 1: Adjusted grading standard of potential ecological risk of heavy metals in Ewhare soil.

E^i_R	Pollution degree	RI	Risk level	Risk degree
$Ei_R < 30$	Slight	RI< 40	A	Slight
$30 \leq Ei_R < 60$	Medium	40 ≤ Ri< 80	B	Medium
$60 \leq Ei_R < 120$	Strong	80≤Ri< 160	C	Strong
$120 \leq Ei_R < 240$	Very Strong	160≤RI 320	D	Very strong
$Ei_R \geq 240$	Extremely strong	RI≥ 320	-	-

E^i_R is the potential ecological risk index of a single element; RI is a comprehensive potential ecological risk index (Source: Jiang *et al.,* 2014).

Statistical analysis

All statistical tests were carried out using Microsoft Excel software and Statistical Package for Social Science (SPSS). All the data obtained were subjected to descriptive analysis. Data analyses for EF, CF, PLI, Igeo and PERI were done by adopting their models into Microsoft excel (2003) and Interpreted.

Results and Discussion

Heavy metals

The mean concentration of heavy metals in (mg/kg) in the soils collected from Ewhare dumpsite is presented in table 2. The concentration of heavy metals were in the following order Fe > Zn > Mn > Cu > Pb > Cd > Cr > Ni > V. Similar results have been obtained by Enuneku *et al,* (2017) in soils associated with high traffic areas in Benin metropolis. Ngole and Ekosse (2012) also reported higher concentrations of metals in soils of a landfill environment. Cadmium reported by Fungee*t al.,* (2017) is one of the most eco-toxic metals with highly undesirable effects on soil health, humans, animal health and plant metabolism in Kabata-Pendias, (2000). Chronic exposure to very low cadmium concentrations can result to insomnia, cardiovascular diseases, anaemia and renal problems (Sharma *et al.,* 2006).

Table 2: Summary of Soil heavy metal Concentrations (mg kg-1) in Ewhare dumpsite and adjoining land

Depth	Site	Fe	Mn	Zn	Cu	Cr	Cd	Pb	Ni	V
0-15cm	Control	921.24	24.32	5.78	10.69	0.4	0.03	0.6	0.18	0.11
0-15cm	DS1	621.1	34.9	59.95	23.1	10.5	10.45	15.15	3.05	2.435
	US1	326.35	18.4	31.5	12.15	5.62	10.62	17.75	1.17	0.935
16-30cm	DS2	477.6	26.95	47.95	16.75	8.14	8.535	12.36	1.68	1.34
	US2	257.95	14.55	24.9	9.605	4.4	10.26	13.6	0.88	0.7
30-45cm	DS3	338.25	19.6	41.3	14.1	5.765	6.74	11.27	1.475	1.23
	US3	219.1	12.675	20.7	6.97	3.22	8.145	11	0.405	0.325

Enrichment Factor (EF)

The results of the EF are presented in table 3.The soil samples showed background or depletion of mineral to a very high enrichment of metals in Ewhare dumpsite. The soils with a very high enrichment of heavy metals were the samples collected at directly within the dumpsite (DS) at a depth of 0-15 cm and 15-30 cm and top soil (0-15cm) of the adjoin land of the dumpsite. Enrichment factor (EF) in this study showed a depletion of iron (Fe) and manganese (Mn), moderate enrichment for copper (Cu), a significant enrichment for zinc (Zn) and nickel (Ni), very high enrichment for chromium (Cr), cadmium (Cd), lead (Pb) and vanadium (V).

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This is likely to be influenced by the municipal waste that are dumped at the site which suggests androgenic origin that is always connected with dumpsites that receives all kinds of waste ranging from domestic to commercial waste(Abayode, 2004).Odukoya, (2015) reported similar results of very high contamination of metals in soils collected from two dumpsite (active and abandon) dumpsite in Lagos State, Nigeria.

Contamination Factor (CF) and Pollution Load Index (PLI)

CFs recorded for various heavy metals in Ewhare dumpsite are presented in table 4 and the PLI values were represented in figure 1. CF in all the metalsanalyzed were higher at the dumpsite (DS) than the adjoining land or upslope (US) location at the same depth. Contamination factor (CF) in this study indicatedlow contamination of Fe, moderate contamination of manganese (Mn) and copper (Cu)at downslope and upslope depth of 0-15cm; considerable contamination of nickel (Ni) and vanadium (V) at downslope and upslope depth of 0-15cm, very high contamination of zinc (Zn), chromium (Cr), cadmium (Cd), and lead (Pb). Ojodomo recorded high level of contamination in soils collected from dumpsite soils in Wukari, North-Eastern Nigeria. Fonge *et al,* (2017) reported high contamination for cadmium (Cd), copper (Cu), zinc (Zn) and mercury (Hg) in soils of a municipal landfill surrounded by banana plantation in the Eastern flank of mount Cameroon. The study reported by Fonge *et al,* (2017)was similar to the results from study with respect to the high contamination of Ni, V, Zn, Cr, Cd and Pb. These metals are used in our manufacturing industries in Nigeria and are commonly used in our homes as well as fungicides, pesticides and herbicides which are our house hold commodities before and after disposal that ends up in our dumpsites.

Table 3. Enrichment factor (EF) of Ewhare Dumpsite and adjoining soil at different depths

Metal	DS1 (0-15cm)	US1 (0-15cm)	DS1 (16-30cm)	US1 (16-30cm)	DS1 (31-45cm)	US1 (31-45cm)
Fe	0.67	0.35	0.52	0.28	0.37	0.24
Mn	1.44	0.76	1.11	0.59	0.81	0.52
Zn	10.37	5.45	8.29	4.31	7.15	3.58
Cu	2.16	1.14	1.57	0.89	1.32	0.65
Cr	26.25	14.05	20.35	11.00	14.41	8.05
Cd	35.4	34.83	34.2	28.45	27.15	22.47

Pb	29.58	25.25	22.67	20.6	18.78	18.33
Ni	16.94	6.50	9.33	4.89	8.19	2.25
V	22.14	8.50	12.18	6.45	11.18	2.95

The pollution load index (PLI) value across all the study areas showed that Ewhare dumpsite is polluted (PLI > 1) by metals. Odukoya,(2015), Ojodomo, (2016) and Fonge *et al,* (2017)reported similar results in their study. The high concentration of metals could have resulted from the decomposition of waste in Ewhare dumpsite.

Table 4: The concentration factor and the pollution load index of Ewhare Dumpsite and adjoining land

Concentration Factor										
Location	**Fe**	**Mn**	**Zn**	**Cu**	**Cr**	**Cd**	**Pb**	**Ni**	**V**	**Pollution Load Index**
DS1 (0-15cm)	0.67	1.44	10.37	2.16	26.25	35.4	29.58	16.94	22.14	8.46
US1 (0-15cm)	0.35	0.76	5.45	1.14	14.05	34.83	25.25	6.5	8.5	4.70
DS1 (16-30cm)	0.52	1.11	8.29	1.57	20.35	34.20	22.67	9.33	12.18	6.19
US1 (16-30cm)	0.28	0.59	4.31	0.89	11.00	28.45	21.00	4.89	6.45	3.70
DS1 (31-45cm)	0.37	0.81	7.15	1.32	14.14	27.14	18.78	8.19	11.18	4.99
US1 (31-45cm)	0.24	0.52	3.58	0.65	8.05	22.47	18.33	2.25	2.95	2.65

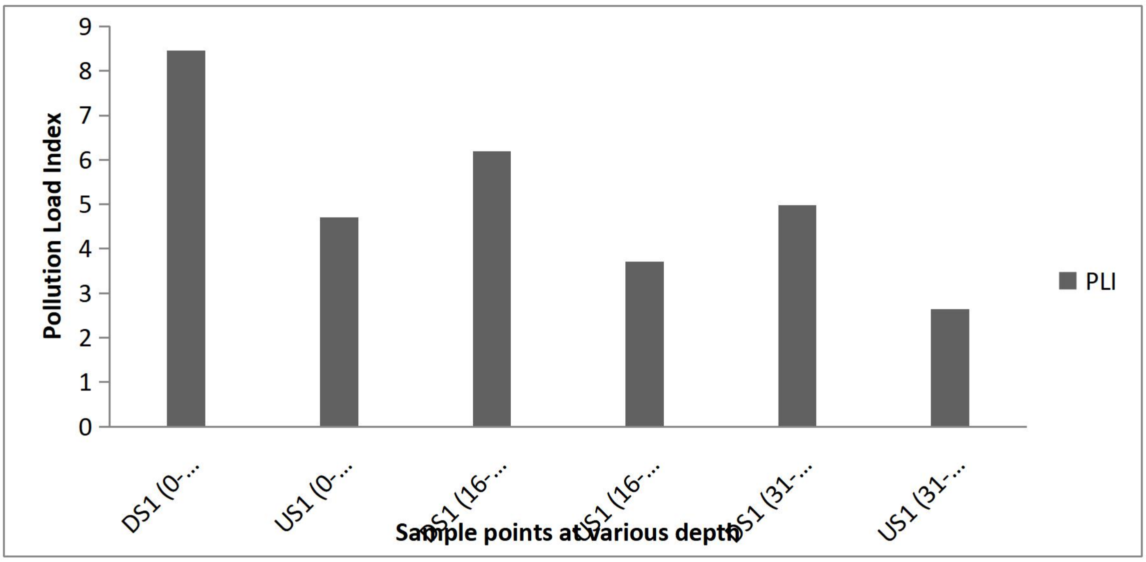

Fig 1: PLI values across the sample points at various depth of the study area

Geoaccumulation Index (*Igeo*)

The calculated*Igeo* values are represented in figure 2. The soils of Ewhare dumpsite falls within the seven classes based on Muller's interpretation. All *Igeo* classes were represented in this study that ranged practically from unpolluted to extremely polluted. Geoaccumulation Index (*Igeo*) in this study showed that soils of Ewhare dumpsite were practically unpolluted (*Igeo* ≤ 0) for Fe and Mn asboth showed negative values of metal contamination. Samples collected for other metals were moderately to heavily polluted for zinc (Zn) and nickel (Ni), heavily polluted for vanadium (V), heavily to extremely polluted for chromium (Cr), cadmium (Cd), and lead (Pb).

Odukoya,(2015) reported moderate to strong pollution for abandoned dumpsite while the active dumpsite also recorded extreme pollution for metals such as Cu, Cd, Pb and Zn. Odukoya,(2015) further opined that the samples with extreme pollution were collected close to the active dumpsite which was also the case for enrichment factor. The result of this study is in line with the report of Odukoya,(2015) as extreme pollution for Cr, Cd and Pb was recorded for soil samples collected from the dumpsite (DS) and the adjoining land (US) top soil of 0-15cm in Ewhare dumpsite.

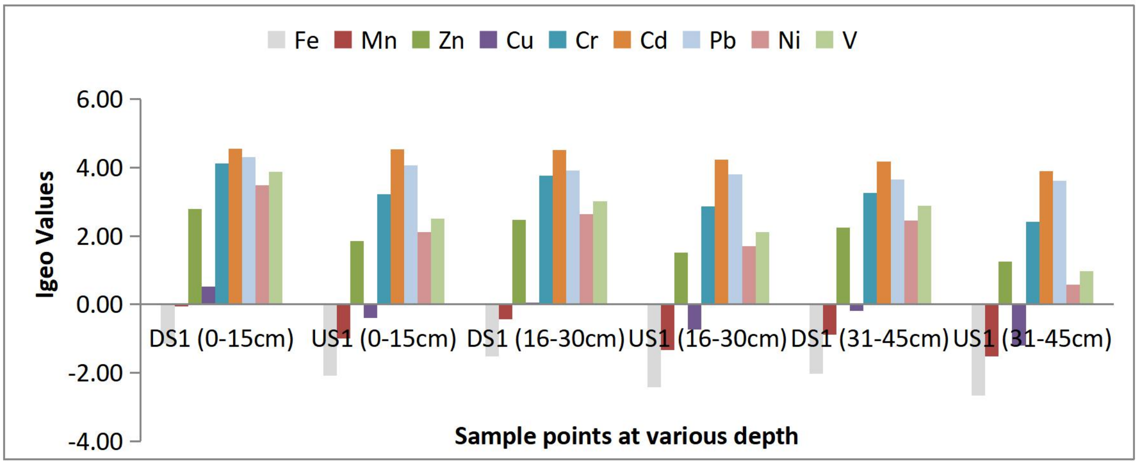

Fig 2: Igeo values across the sample points at various depth of the study area

Table 5: Potential Ecological Risk Index

	Mn	Zn	Cu	Cr	Pb	Ni	Cd	RI
T^i_R	1.00	1.00	5.00	2.00	5.00	5.00	30.00	-
				$E^i_{R\ values}$				
DS1 (0-15cm)	1.44	10.37	10.8	52.5	147.9	84.7	1062.0	1370.0
US1 (0-15cm)	0.76	5.45	5.7	28.1	126.25	32.5	1044.9	1240.0

DS1 (16-30cm)	1.11	8.29	7.85	40.7	113.35	46.65	1026	1244.0
US1 (16-30cm)	0.59	4.31	4.45	22	105	24.45	853.5	1014.3
DS1 (31-45cm)	0.81	7.15	6.6	28.82	93.9	40.95	814.2	992.4
US1 (31-45cm)	0.52	3.58	3.25	16.1	91.65	11.25	674.1	800.5

Potential ecological risk index (PERI)

The Potential Ecological Risk Index of Ewhare dumpsite is presented in table5.Five pollution degree and four risk levels were recognized in relation to the potential ecological risk index and was used to characterize the soils obtained from Ewhare dumpsite and adjoining land.

The PERI in this study showed slight pollution for manganese (Mn), zinc (Zn) and copper (Cu), medium pollution for chromium (Cr), strong pollution for nickel (Ni), very strong pollution for lead (Pb) and an extremely strong pollution for cadmium (Cd). Odukoya, (2015) reported low risk for Cr, moderate risk for Zn, low to moderate risk for Cu while As and Pb had considerable risk in the active dumpsite similar to the result obtained from this study at Ewhare dumpsite.The risk index (RI) for Ewhare dumpsite indicated a very strong risk or level D for the dumpsite soil (downslope) and the top soil (0-15cm) of the adjoining land.respectively; this result was similar to that obtained from from high traffic areas in Benin metropolis (Enuneku, *et al,* 2017).Mn, Zn, CU, Cr, Pb and Ni show low ecological risk (RI < 150) in all sample depths in the study area except Cd which shows very high ecological risk (RI> 600) in all sample depths in the study area.

Conclusion

Soil is very important in ecosystem research as it is the place where many types of interactions take place between minerals, air, water and biota(Ukpebor *et al.,* 2003).This study assessed various contamination indices of heavy metals at different soil depths of Ewhare dumpsite and adjoining land in Warri, Delta State. The result showed the concentration of metals was generally high and were in the following order of decreasing concentration: Fe > Zn > Mn > Cu > Pb > Cd > Cr > Ni > V. Several indices used for assessing the concentrations also suggest a high level of soil pollution of Ewhare dumpsite as expected. The major contaminants were Zn, Mn, Cu, Pb, Cd, Cr, Ni, and V, although at different degree of contamination. This can be linked to the decomposition of waste in Ewhare dumpsite without proper treatment measures thus resulting in leachate plume that migrate from the dumpsite to the soil within and may even go further and beyond the immediate vicinity of the site. Mn, Zn, CU, Cr, Pb and Ni show low ecological risk (RI < 150) in all sample depths in the study area except Cd which shows very high ecological risk (RI> 600) in all sample depths in the study area. In view of the high level of pollution of Ewhare dumpsite, there is an urgent need to develop a soil and water monitoring programs in order to ascertain and prevent surface water and groundwater contamination; this is particularly significant in view of the location of this dumpsite in Nigeria's Niger delta area near the Atlantic Coastline. Although not assessed, there is the need to evaluate the organic contaminants in the soil as well.

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