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CONTAMINATION AND ECOLOGICAL RISK ASSESSMENT OF POTENTIALLY TOXIC ELEMENTS IN SOILS AROUND AROUND OLOMORE DUMPSITE IN ABEOKUTA, SOUTH WESTERN, NIGERIA

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ABSTRACT
Unsystematic deposition of wastes due to urbanization and industrilization has led to release of contaminants in soils and nearby water sources. This study investigated the effect of wastes on the concentrations of potentially toxic elemets (PTEs) in soils around a solid waste dumpsite, assessed their contamination status and ecological risk on the surounding area. Ten soil samples each collected from dumpsite, downslope, upslope and control site locations were analysed for Fe, Pb, Mn, Cd, Cu, Zn, As, Co, Cr and Ni concentrations were determined using Atomic Absorption Spectophotometer. The concentrations of PTEs in the soils were in order of Fe> Mn> Zn> Pb> Cu> Ni> Co> Cr> As > Cd. Concentrations of the Fe, Cu, Zn, Mn, Pb, Ni, Co and Cr in the studied soils were within the recommended values with the exception of Cd from dumpsite and downslope soils. Concentrations of PTEs are substantially higher in dumpsite than soils from other locations. The contamination factor and degree of contamination exhibit sparing to relative contamination of PTEs in soils. The geoaccumulation index values suggested non polluted to relatively polluted with PTEs in the soils while ecological risk indices showed sparing risk of the potential toxic elements in soils from the surrounding area. This study has shown the anthropogenic effects of wastes on the surrounding area.

KEY WORDS
Anthropogenic, accumulation, wastes, anthropogenic influence, noxious.

The existence of a chemical or substance in exceeding concentrations above the normal amounts may be detrimental to an organism and humans (FAO, 2015). Contamination has become a major ecological concern due to the undying time of potentially toxic elements (PTEs) in nature and its contamination effects on soils (Mamut et al. 2015). Potentially toxic elements can come from natural and anthropegenic source, but can become noxious and injurious at high concentrations (Khelfaoui et al. 2020). Potentially toxic elements (PTEs) are common and vital uncontrollable contaminants that influence copious microbial activities in soil. The detrimental effect of potentially toxic elements depends on the number of elements that are bioaccumulated by absorption, migration, and transformation (Akintola, 2014). The propinquity of urban soils to humans is increasing the likelihood that soil may be a carrier of of contaminats and other dangeous substances into the human body through inhalation, ingestion or dermal contact (Abrahams, 2002). In most developing countries like Nigeria, dumpsites are often used for planting of food crops and vegetables due to their richness in nutrients. The physicochemical properties of soil customarily affect the variety of vegetation available in such land. For example, soil structure and acidity affects the absorption and accumulation of mineral elements by plants (Ekere et al, 2014). The types and concentration of toxic elements in soil and crops around dumpsites are subject to the wastes types, run-off, topography, and level of scavenging (Ogbonna et al., 2009). Contamination of soil by PTEs may pose health risk to humans through the food chain and can also lead to reduction in food quality. Crops and vegetables grown in soils contaminated with potentially toxic elements have greater susceptibility to uptake these elements. Consumption of vegetable has increased in recent years due to its health benefits and uptake of PTEs by vegetables is a major pathway for toxic elements through the soil to enter the food chain and bio-accumulates leading to health risk (Guerra et al., 2012; Jena et al., 2012; Akintola et al; 2019, Ihedioha et al., 2021). The long term exposure to PTEs can have carcinogenic, central and peripheral nervous system, and circulatory effects on human (Nwankwo et al., 2019). Thus, a need to constantly examine the level of PTEs in soils and their bioaccumulation in the edible crops or vegetables to ensure that the accepted levels are not exceeded. This study aimed examined the concentrations of potentially toxic elements in soils around the Olomore dumpsite, assess their contamination and ecological risk on the environment.

MATERIALS AND METHODS OF RESEARCH

The study area, Olomore dump site lies between Latitudes 7° 5′N to 7° 20′N and Longitudes 3° 17′ E to 3° 27′E in Abeokuta, South-western Nigeria (Figure 1). Topography of the area is undulating with an elevation value of 157m above sea level. The area are within sub-humid tropical region of Nigeria, dominated by two distinct wet and dry seasons with an annual rainfall of 1270mm and temperature of 28°C. Geologically, the area falls within Crystalline Basement Complex of Nigeria consisting of igneous and metamorphic rocks. River Ogun flows through the study area and split the town into two.

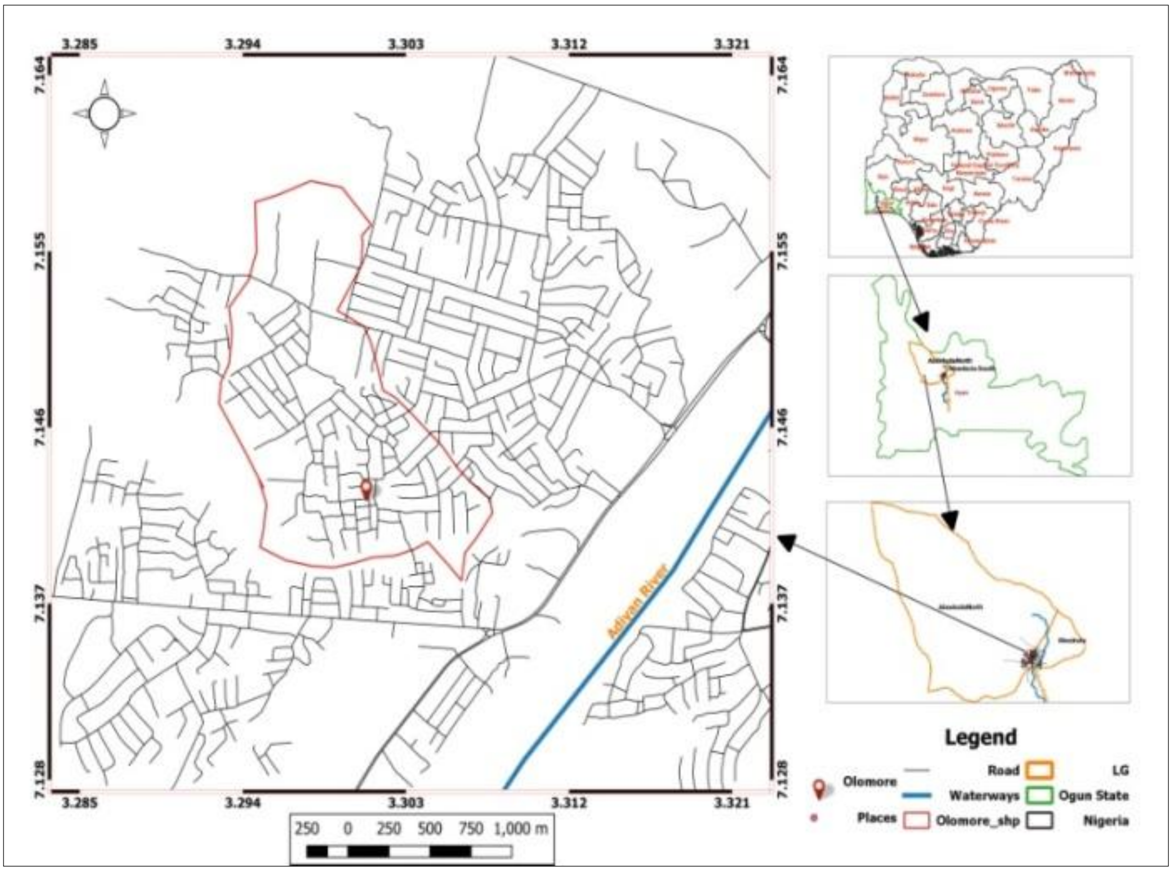

Figure 1 – Location map of the study area

Soil samples were collected within and around the dumpsite at the depth of 0.15cm. Ten soil samples each were collected randomly within the dumpsite and at 1000m upslope side of the dumpsite. Ten soil samples each were also collected from downslope and upslope side of the dumpsite at distance of 20m, 40m, 60m, 80m and 100m (2 samples from each of the sampling points). Samples were cautiously handled, put in a polythene bags and consequently labeled. Air drying the soil samples were done for 24hrs and then sieved with 0.5mm sieve. Sample analysis was done by weighing 0.5g of the 0.5mm sieved samples into a 50ml beaker. Ten (10) ml of an acid mixture and nitric acid in ratio of 1:2 was added to the measured samples under a fume cupboard. The beaker content was placed on a digester or a heating mantle to undergo digestion at 105°C for about 20 minutes until the colour changes from brownish red to colourless. The digest was allowed to cool and made up to 25ml distilled water. The content was read on Buck scientific Atomic Absorption Spectophotometer model 210/211 VGP to determine heavy metals such as Fe, Pb, Mn, Cd, Cu, Zn, As, Co, Cr and Ni.

Analysis of data were done by using descriptive statistics and one-way analysis of variance was used to compare the mean values of the determined parameters in soils from four location sites in and around the dumpsite. Geochemical indices such as contamination indices (contamination factor and degree of contamination), geoaccumulation index(Igeo) and ecological risk indices (ecological risk and risk index) were used to assess contamination and ecological risks of the PTEs in the soils.

Contamination factor (CF) and degree of contamination (CD) used to describe the contamination of of PTEs in soil are presented in Equation 1 and 2 (Håkanson,1980).

$$\mathrm{CF} = \frac{\mathrm{Cn}}{\mathrm{Cb}} \qquad (1)$$

CF is the Contamination factor (Cf), Cn is the mean of the concentrations of heavy metals from at least five sampling points, Cb is the background concentration of heavy metal. The world average elemental concentrations in mg/kg for Fe (47,200), Cu (45), Zn (95), Pb(20), Mn(850), Ni(68), Cd(0.30), As (1.5), Cr(90) and Co (19) stated by Barbalace (1995) were used as background values:

$$\mathrm{Cd} = \sum \mathrm{CF} \qquad (2)$$

Classification of contamination factor (CF) and degree of contamination (CD) by Håkanson (1980) is presented in Table 1

Table 1 – Classification of Contamination factor (CF) and Degree of contamination (CD) modified after Hakanson (1980)

Categories	Contamination factor (CF)			
1	CF<1	sparing contamination	CD<6	sparing degree of contamination
2	1<CF<3	relative contamination	6<CD<12	relative degree of contamination;
3	3<CF<6	significant contamination	12<CD<24	significant degree of contamination
4	6<CF	awful contamination	CD≥24	awful contamination

Geoaccumulation index (Igeo) as given by Müller (1979) is used to assess the pollution level of PTEs in the studied soils (Banat et al., 2005, Buccolieri et al., 2006). Formula of Igeo is shown in Equation 3 while the seven classes of Igeo as given by Müller (1979) is presented in Table 2.

$$Igeo = \log_2 Ci/1.5Cn \qquad (3)$$

Where: Ci is the concentration of the determined elements in the soil. Cn is the background concentration of the element while 1.5 is the conversion factor.

Table 2 – Geoaccummulation index (Igeo) modified after Muller (1979)

Class	Geoaccummulation index (Igeo)	Grade
1	*I*geo≤0	non-polluted
2	0<*I*geo≤1	non-polluted to relatively polluted
3	1<*I*geo≤2	relatively polluted
4	2<*I*geo≤3	relatively to notably polluted
5	3<*I*geo≤4	notably polluted
6	4<*I*geo≤5	notably to awfully polluted
7	*I*geo>5	awfully polluted

Ecological risk (ER) and risk index (RI) is calculated in Equation 4 and 5. The toxic response and classification as given by Hakanson (1980) is presented in Table 3.

$$ER = Tr\ x\ CF \qquad (4)$$

Where Tr is the toxic-response factor for a given substance (Table 3.) and CF is the Contamination factor.

$$\mathrm{RI} = \sum \mathrm{ER} \qquad (5)$$

Table 3 – Toxic- response Factor and Classification of Potential ecological risk modified after Hakanson (1980)

Element	Toxic response (Tr)	CLASS	Ecological risk (ER)		Risk indx (RI)	
Cd	30	1	ER<40	sparing risk	RI<95	sparing risk
Ni	5	2	40≤ER<80	relative risk	95≤RI<190	relative risk
Cu	5	3	80≤ER<160	noticeable risk	190≤RI<380	noticeablerisk
Pb	5	4	160≤ER<320	signifcant risk	RI>380	significant risk
Cr	2	5	ER≥320	severe risk		
Zn	1					
Co	1					
Mn	1					
As	10					

RESULTS AND DISCUSSION

Mean values of PTEs in soils from the four location sites are presented in Table 4. The recommended standard values given by FAO/WHO (2011), the upper continental crust, world average values and European average values as stated by Kabata-Pendias (2011) are also presented in Table 4. The respective mean concentrations of determined PTEs from dumpsite, downslope, upslope and control soils were Fe (112.09±4.45, 36.78±1.27; 22.39±0.95, 15.90±0.56), Zn (64.22± 1.12, 11.33±0.11, 6.83±0.05, 2.11±0.01), Cu (32.87±0.29, 13.72±0.23, 4.78±0.09, 1.10±0.01), Pb (35.89±1.01, 10.53±0.13, 6.45±0.09, 2.56±0.05), Mn (84.20±2.78. 31.40±0.59, 31.40±0.59, 15.10±0.25, 6.80±0.17), Ni (15.09±0.87, 9.09±0.21, 6.57±0.08, 5.11±0.05), Co (6.22±0.31, 2.08±0.04, 1.01±0.01, 0.56±0.01), Cr (8.79±0.08, 2.85±0.01, 1.44±0.02, 1.06±0.01), Cd (1.11±0.05, 0.55±0.05, 0.25±0.02, 0.20±0.01) and As (1.95±0.16, 1.43±0.09, 0.68±0.05, 0.51±0.01) in mg/kg. Concentrations of the studied PTEs were significantly higher in dumpsite soils than soils from other three locations at p≤0.05. The results were within the recommended values given by FAO/WHO (2011) and Kabata-Pendias (2011). The concentrations of PTEs in the soils were in order of Fe> Mn> Zn> Pb> Cu> Ni> Co> Cr> As > Cd. However, concentrations of As and Cd in soils from dumpsite and downslope location were higher than the recommended values given in Table 4. Though the source of PTEs may be geogenic but their elevated values of PTEs suggest anthropogenic impact of wastes. This is in line with the reports of many researchers that high concentrations of PTEs in soils is as indication of anthropogenic sources that contribute significantly to environmental pollution (Akintola, 2014; Akintola and Bodede , 2019; Agyeman et al. 2021).

The regression plots of mean concentrations in soil from the four locations are presented in Figure 2a to Figure 2j. Regression plots indicate negative correlation coefficients for PTEs determined in down slope and upslope soils with distances up to 100m away from the dumpsite. The values of R^2 for PTEs concentrations in downslope soils with distances from dumpsite ranged from 0.89 to 0.99 (r= -0.99 to -0.94) while R^2 from upslope soils are between 0.76 and 0.98 (r = -98 to -0.87). The negative correlation coefficient (r) indicated decrease in concentrations of PTES with distances away from the dumpsite. However, the impact of the wastes is more on the downslope soil than the upslope soil when compared with PTEs concentrations from the dumpsite and control soils (Figure2a-2j). Also the strong correlation coefficient values indicate the impact of wastes on the concentrations of the PTEs.

Table 4 – Mean values of PTEs concentration in soils and the recommended values

Study Sites	PTEs in mg/kg									
	Fe	Zn	Cu	Pb	Ni	Cd	Mn	Co	Cr	As
Dumpsite	112.09±4.45[a]	64.22±1.12[a]	32.87±0.29a	35.89±1.01[a]	15.09±0.87[a]	1.11±0.05[a]	84.20±2.78[a]	6.22±0.31[a]	8.79±0.08a	1.95±0.16[a]
Downslope	36.78±1.27[b]	11.33±0.11[b]	13.72±0.23[b]	10.53±0.13[b]	9.09±0.21[b]	0.56±0.05[b]	31.40±0.59[b]	2.08±0.04[b]	2.85±0.01b	1.43±0.09[b]
Upslope	22.39±0.95[c]	6.83±0.05[c]	4.78±0.09[c]	6.45±0.09[c]	6.57±0.08[c]	0.25±0.02[c]	15.10±0.25[c]	1.01±0.01[c]	1.44±0.02c	0.64±0.05[c]
Control site	15.90±0.56[d]	2.11±0.01[d]	1.10±0.01[d]	2.56±0.05[d]	5.11±0.05[d]	0.20±0.01[c]	6.80±0.17[d]	0.56±0.01[d]	1.06±0.01d	0.51±0.01[c]
Recommended values										
FAO/WHO (2011)	100-700	300	100	100	50	0.30	500	50	100	1.50
UCC	300	70.00	17.33	15.00	20.00	0.10	900	50	100	1.80
WAV	250	70	29.90	27	29	0.41	488.00	28.25	59.50	6.83
EAV	524.00	68.10	17.30	32	37	0.28	524.00	46.10	94.80	11.63

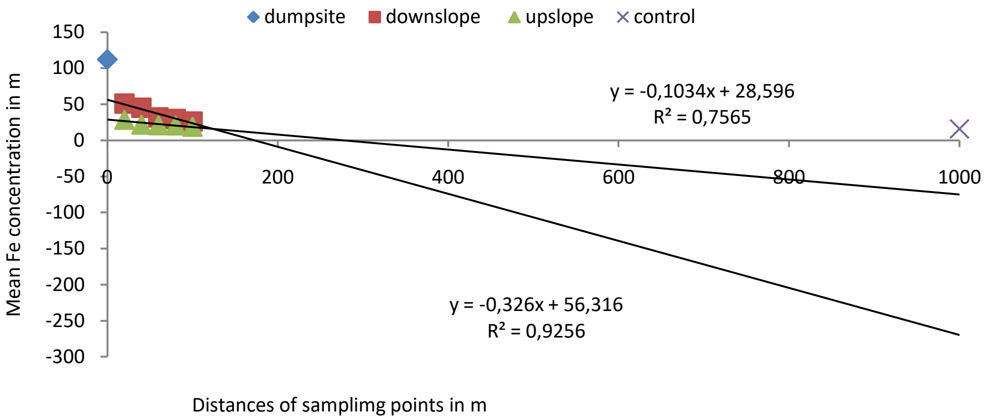

Figure 2a – Mean concentration of Fe with distances from dumpsite

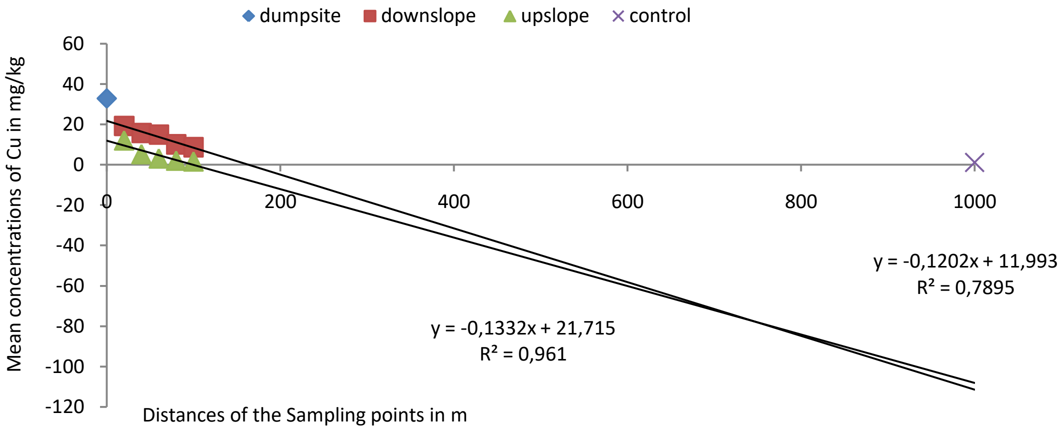

Figure 2b – Mean concentration of Cu with distances from dumpsite

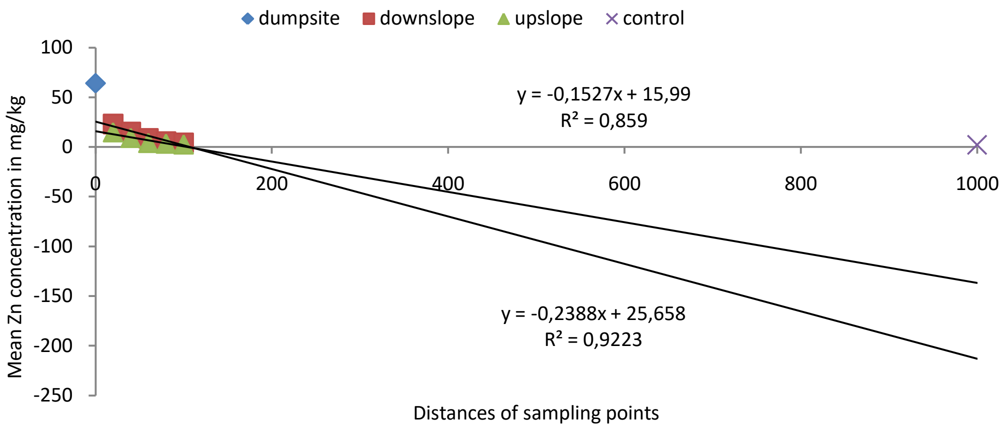

Figure 2c – Mean concentration of Zn with distances from dumpsite

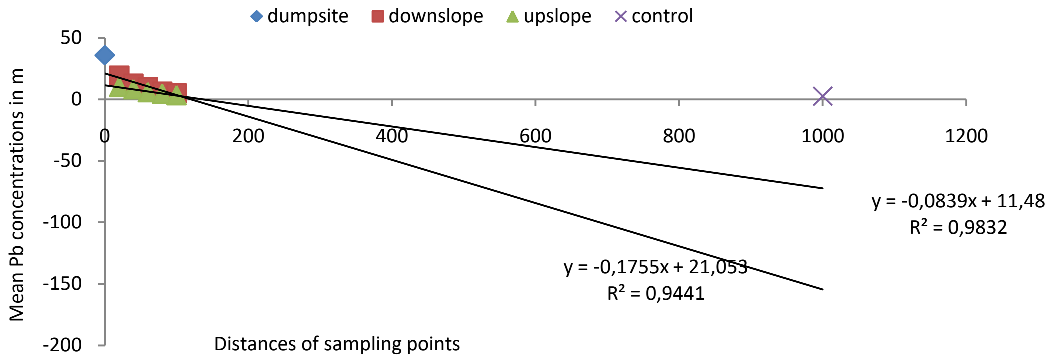

Figure 2d. Mean concentration of Pb with distances from dumpsite

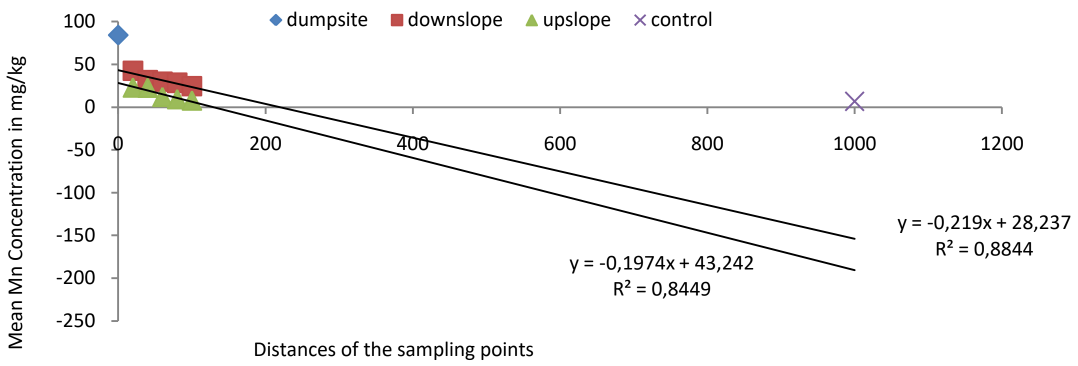

Figure 2e. Mean concentration of Fe with distances from dumpsite

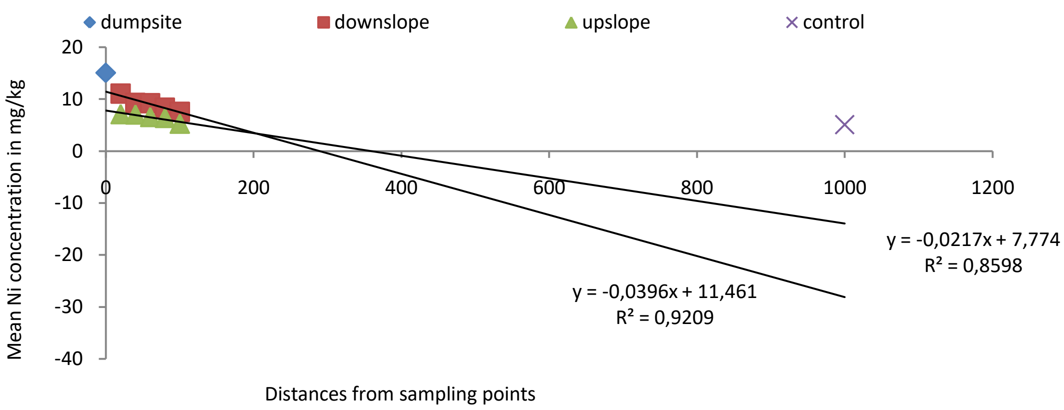

Figure 2f. Mean concentration of Fe with distances from dumpsite

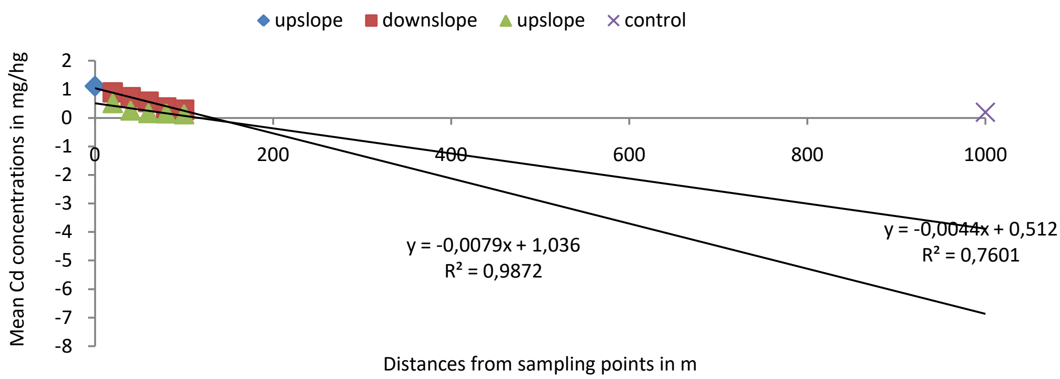

Figure 2g – Mean concentration of Cd with distances from dumpsite

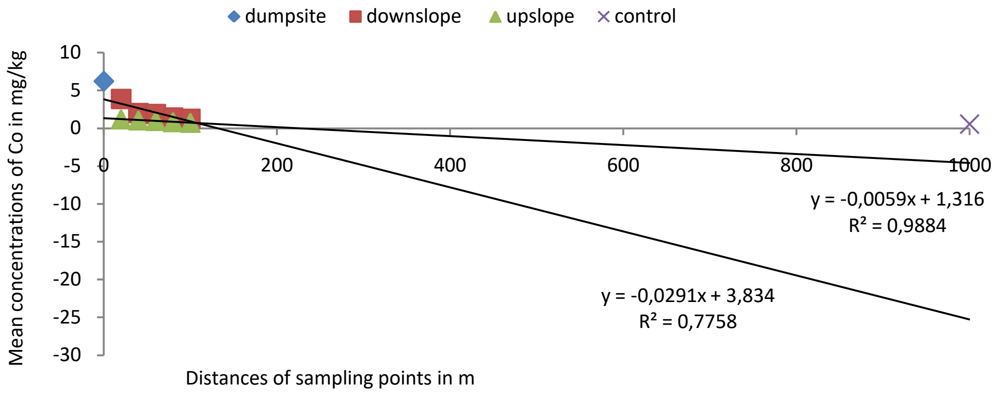

Figure 2h – Mean concentration of Co with distances from dumpsite

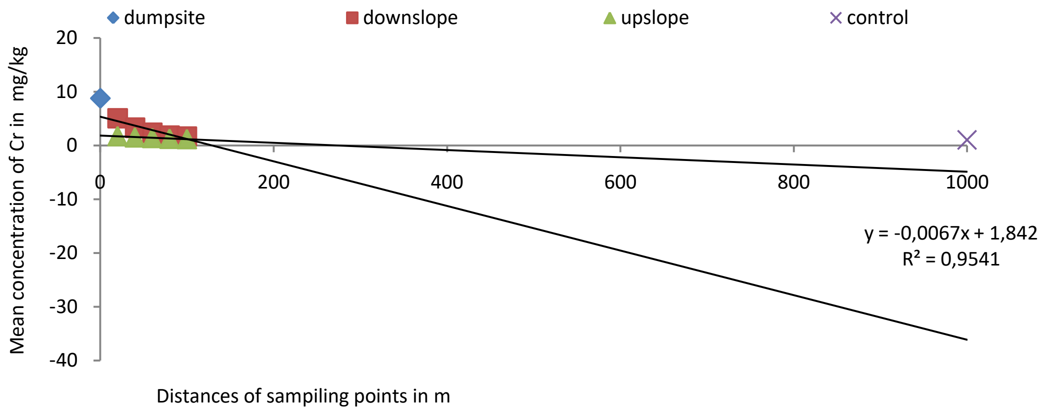

Figure 2i – Mean concentration of Cr with distances from dumpsites

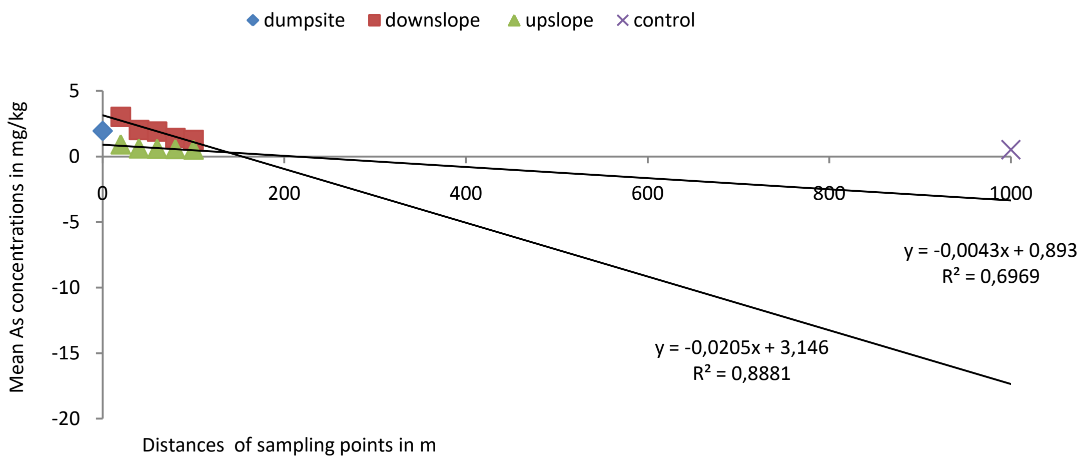

Figure 2j – Mean concentration of As with distances from dumpsite

Contamination factor (CF) and degree of contamination values are presented in Table 5. Contamination factor (CF) showed the order of Cd> As> Pb>Cu>Zn>Co> Ni> Cr> Mn> Fe for soils within the dumpsite while CF showed the order of As> Cd> Pb>Cu>Zn>Co> Ni> Cr> Mn> Fe in soils from downslope, upslope and control. Contamination factor values were significantly higher in dumpsite soils at P≤0.05 than soils from other locations. Anthropogenic impacts of the wastes are more on the soils closer to the dumpsite than those farther away. This result further affirms the results of regression analysis that the concentrations of PTEs decreased with distances from the dumpsite. Values of CF showed sparingly contaminated

(< 1) with Fe, Zn, Cu, Co, Cr, Ni and Mn in the studied soils and relatively contaminated with Cd, Pb and As contamination (>1) in dumpsite soils (Table 1 and 5). The degree of contamination (CD =7.54) is higher in dumpsite soils, followed by downslope (CD =3.60) and upslope soils (CD=1.89) while control soils have the lowest CD value of 1.18. The mean CD value of PTEs from the four location sites is 3.55 (Table 5). This value is less than 6, indicating sparingly degree of contamination of the studied PTEs on the environment as given by CD by Hakanson (1980) in Table 1. This may be attributed to the age of the dumpsite, types of deposited wastes and the rock types in the area. The contamination factor and contamination degree values in this study were lower to those reported by Akintola (2014) and Akintola and Bodede (2019).

Table 5 – Contamination factors (CF) and Contamination degree (CD) values of Potentially Toxic elements (PTEs) in the soil samples

Metals	Contaminatin factors (CF)				
	Dumpsite soils	downslope soils	upslope soils	control soil	Mean CF
Fe	0.003[a]	0.001[b]	0.001[b]	0.0003[c]	0.003
Zn	0.67[a]	0.12[b]	0.07[bc]	0.02[c]	0.22
Cu	0.71[a]	0.31[b]	0.11[c]	0.02[d]	0.28
Pb	1.75[a]	0.55[b]	0.35[bc]	0.15[c]	0.65
Mn	0.10[a]	0.04[b]	0.02[bc]	0.01[c]	0.04
Co	0.33[a]	0.11[b]	0.08[bc]	0.04[c]	0.14
Ni	0.23[a]	0.13[b]	0.10c	0.07[c]	0.13
Cr	0.11[a]	0.03[b]	0.02[b]	0.01[c]	0.05
Cd	1.86[a]	1.00[b]	0.57[bc]	0.40[c]	0.96
As	1.77[a]	1.31[b]	0.58[c]	0.46[c]	1.03
Contamination Degree (CD)=∑CF					MEAN CD
Contamination Degree (CD)	7.54[a]	3.60[b]	1.89[c]	1.18[cd]	3.55

Note: Values with different letters within the same row were significantly difference at P≤0.05.

Table 6 – Geoaccumulation index (Igeo)) values of Potentially Toxic elements (PTEs) in the soil samples

Metals	Geoaccumulation index (Igeo))				
	Dumpsite soils	downslope soils	upslope soils	control soil	Mean Igeo
Fe	-7.64	-9.38	-9.38	-7.79	-8.55
Zn	-0.03	-2.47	-3.25	-5.06	-2.70
Cu	0.10	-1.06	-2.60	-5.06	-2.16
Pb	1.40	-0.27	-0.92	-2.12	-0.48
Mn	-2.73	-4.00	-5.06	-5.05	-4.21
Co	-1.10	-2.60	-3.02	-4.06	-2.70
Ni	-1.51	-2.25	-2.74	-3.25	-2.44
Cr	-2.60	-4.47	-5.06	-6.05	-4.55
Cd	1.48	0.56	-0.21	-0.73	0.28
As	1.42	0.98	-0.20	-0.54	0.42

The mean values of geoaccumulation index of PTEs from the the four locations in this study is presented in Table 6. The Igeo values of Fe, Zn, Mn, Co, Ni and Cr ranged from -7.64 to -0.003 while the values of Cu, Cd and As were between 0.10 and 1.48 in soils from dumpsite. The values of Igeo in soils from downslope soils for Fe, Zn, Cu Mn, Co, Ni and Cr were between –9.38 and-0.27 while Igeo values for Cd and As were 0.56 and 0.98 respectively. The Igeo values of PTEs in soils form upslope and control soils ranged from -0.20 to-0.98. This results shows that the soils are non-polluted to relatively polluted with PTEs from the study area (Table 2).

The calculated ecological risk (ER) and risk index (IR) is presented in Table 5. The ER values from the four lacations for Fe, Zn, Pb, Cu, Mn, Ni, Cr, Co and As; Cd from the downslope, upslope and control soils were between 0.002 and 30.00 and this is less than 40, indicationg sparing potential risk (Table 3). The ER value of Cd from dumpsite soils is 55.80 (Table 5) and this indicate relative risk (40≤ER<80). The ER values showed the order of Cd>

As>Pb>Cu>Zn>Co> Ni> Cr> Mn> Fe. ER values were significantly differ from each location sites at P≤0.05 (Table 5) indicating the influence of wastes on the soils.

Table 7 – Ecological risk (ER) and Risk index (RI) values of Potentially Toxic elements (PTEs) in the soil samples

Metals	ECOLOGICAL RISK (ER)				
	Dumpsite soils	downslope soils	upslope soils	control soil	Mean ER
Fe	0.02[a]	0.01[b]	0.01[b]	0.002[c]	0.01
Zn	3.35[a]	0.60[b]	0.35[c]	0.10[d]	1.1
Cu	3.55[a]	1.55[b]	0.55[c]	0.10[d]	1.44
Pb	8.75[a]	2.75[b]	1.75[c]	0.75[d]	3.5
Mn	0.10[a]	0.04[b]	0.02[c]	0.01[c]	0.04
Co	0.33[a]	0.11[b]	0.08[c]	0.04[d]	0.14
Ni	0.23[a]	0.13[b]	0.10b[c]	0.07[c]	0.13
Cr	0.22[a]	0.06[b]	0.04[c]	0.02[d]	0.09
Cd	55.80[a]	30.00[b]	17.10[c]	12.00[d]	28.72
As	17.70[a]	13.10[b]	5.80[c]	4.60[c]	10.40
RISK INDEX (RI) = ∑ ER					MEAN RI
RI	90.04[a]	48.35[b]	25.70[c]	17.69[d]	45.44

Note: Values with different letters within the same row were significantly difference at P≤0.05.

The risk index (RI) values from the four locations ranged from 17.69 to 90.04. The remarkable highest value of RI was found in soils from dumpsite when compared with soils from other sites. This is ascribed to decomposition of the deposited wastes that releases toxic elements in form of leachates. These leachates during the rainy season infiltrate and percolate into surrunding soils through the runoff and erosion. Overtime, the toxic elements from the leachates accumulated in the soils. Thus area that are closer to the dumpsite will be more affected than those that are far away. Apart from this, soils the downslope side will be more affected than those from upslope area because leachates will flow from area with high elevation to area with low elevation. This explained why the downslope side of the dumpsite is more affected with the infuence of wastes by the accumulation of these toxic elements in the soil. Risk index value is less than 95 indicating sparing potential eclogical risk index according to classification of potential ecological risk index presented in Table 3.

CONCLUSION

This study has conveyed the effects of wastes on concentration of potental toxic elements in soils from the study area. The PTEs concentration are substantially higher in soils from dumpsite and downslope locations. Concentrations of the Fe, Cu, Zn, Mn, Pb, Ni, Co and Cr in the studied soils were within the recommended values with the exception of Cd from dumpsite and downslope soils. Concentrations of PTEs in the soils were in order of Fe> Mn> Zn> Pb> Cu> Ni> Co> Cr> As > Cd. Negative and strong correction coefficients gathered from the concentrations of PTEs and distances from dumpsite is an indication of anthropogenic effect of wastes on the hevels of PTEs in soils. The contamination factor and degree of contamination exhibit sparing to relative contamination of PTEs in soils. The geoaccumulation index values suggested non-polluted to relatively polluted of PTEs in soils while ecological risk indices showed that PTEs have sparing risk on the surrounding area. This study has shown the anthropogenic impact of wastes on the sourrounding area.

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