Heavy metals concentration in the dumpsite soils using geo-accumulation index and ecological risk assessment

Musa John Jiya[1], Jerry David Bala[2], Hassana Ibrahim Mustapha[3], Ibrahim Abayomi Kuti[1*], Elijah Tasdo Musa[3], Yerima Ibrahim Yerima, Enebojojo Sunday Daniel[1], Musa Paul Akos[1]

(1. *Department of Agricultural and Bioresources Engineering, Federal University of Technology, P. M. B. 65, Minna, Nigeria;*
2. *Department of Microbiology, Federal University of Technology, P. M. B. 65, Minna, Nigeria;*
3. *Central Research Laboratory, University of Ilorin, P. M. B. 1515, Ilorin, Nigeria*)

Abstract: This study examines the pollution, geo-accumulation index and the ecological risk assessment of heavy metal concentrations in dumpsites in Kogi, Nasarawa and Niger States of North Central Nigeria. Analysis of the soil from the dumpsites indicates the presence of Aluminum (Al), chromium (Cr), copper (Cu), manganese (Mn), iron (Fe) and zinc (Zn) at the various dumpsites. The accumulation of heavy metals in agricultural soils is of increasing concern because of food safety, potential health risks and its detrimental effects on the soil ecosystem. The pollution index of Cr is an alarming 30.83, 9.69, 13.21, 24.33, 24.10 and 16.54 in Lokoja, Kabba, Okene, Borgu, Bida and Minna respectively. The concentration of Cu was observed to be 48.10, 29.57 and 29.41 in Borgu, Kabba and Minna respectively while the pollution index of Fe was 10.36 in Okene and 15.33 in Kabba. The result of this study shows that heavy metals are present in the study area at the different level of contamination, the geological accumulation of Cu, Cr and Zn in Minna, Borgu and Bida dumpsites indicate an extreme contamination of the soil and require remediation actions to reclaim most of the dumpsites.

Keywords: dumpsites, ecological, geo-accumulation index, heavy metal, pollution, solid waste

Citation: Jiya, M. J., J. D. Bala, H. I. Mustapha, I. A. Kuti, E. T. Musa, Y. I. Yerima, E. S. Daniel, and M. P. Akos. Heavy metals concentration in the dumpsite soil using geo-accumulation index and ecological risk assessment. Agricultural Engineering International: CIGR Journal, 21(3): 7–17.

1 Introduction

Due to urbanization, indiscriminate dumping and numerous local industries like Gold and stone mining, heavy metals in soil are increasing in the area (Aydi, 2015). Heavy Metals as defined by Lentech (2009) and Zaini et al. (2013) are any metallic chemical element that has a relatively high density and is toxic or poisonous at low concentrations. It also referred to as elements in the periodic table having an atomic number more than 20 or densities more than 5 g cm^{-3} (Duffus, 2002). This metal has the potential of impacting on the biological system greatly. Heavy metals become toxic inhuman when they are not metabolized by the body and accumulated in the soft tissues (Eriyamremu et al., 2005; Muchuweti et al., 2006; Satarug et al., 2000). Aluminum (Al), chromium (Cr), lead (Pb), zinc (Zn), manganese (Mn) and iron (Fe) are all naturally occurring substances which are often present in the environment at low levels and if in larger amounts they become dangerous. These metals find their way to the agricultural soil through mining and smelting of metallic element and metal scraps, electroplating, application of fertilizer and pesticides, sludge dumping and municipal solid waste dumping (Sabri et al., 2013; Oguzie et al., 2002; Lawson, 2011; Lee et al., 2006; Vidal et al., 2000; Speir et al., 2003; Razo et al., 2004; Remon et al., 2005; and Mudgal et al., 2010).

Received date: 2018-07-27 **Accepted date:** 2018-12-06

*** Corresponding author: I. A. Kuti,** Department of Agricultural and Bioresources Engineering, Federal University of Technology, P. M. B. 65, Minna, 920000, Nigeria. Email: abykuti6@futminna.edu.ng. Tel: +2348066840291.

On a daily basis, unwanted materials are dropped within the environs of our immediate community leaving heaps of municipal solid waste. Sometimes these materials are left to degrade at the point of disposal while some are collected by waste management agencies and dispose at landfills or municipal waste dumpsite. Dumpsite is the most common and oldest form of waste treatment. Most of which lack basic engineering technicality to mitigate soil and groundwater contamination in most developing countries like Nigeria (Abdus-Salam et al., 2011). This uncontrolled and haphazard dumping of solid wastes around agricultural soil and water body violate many health and social ethics in keeping a safe society.

Geo-accumulation index and ecological risk assessment are used to assess pollution caused by heavy metals in soil (Aydi, 2015). Shittu et al. (2017) examined the heavy metal contamination in dumpsites environment using pollution indices and their results show that the soils are highly polluted with heavy metals. In addition, Geo-accumulation index calculated showed that soils were in the category of unpolluted to moderately polluted levels and suggested that monitoring of heavy metals be investigated to ascertain the long-term effects of anthropogenic impact and heavy metal bioavailability. Koki and Jimoh (2013) determined heavy metals such as Cr, Fe, Zn, Cu, Pb, and Cd in soils from dump site of tanneries and farmlands in Challawa Industrial Estate Kano and their results show that the heavy metals were in increasing order. Ediene and Umoetok (2017) determined the concentration of heavy metals in soils at the municipal dumpsite in Calabar metropolis using pollution index and their results show that the heavy metals concentrations in the dumpsites were greater than that of the control soil. In view of these, the study aimed at determining the presence of Al, Cr, Cu, Pb, Zn, Mn, and Fe as well as their level of concentration in Kogi, Niger and Nassarawa States of North Central, Nigeria using geo-accumulation index and ecological risk assessment.

2 Material and method

2.1 Study areas

Nasarawa State is one of the north central states of Nigeria with a total land area of 27,290 km^2 with a population of about 1,869,377 people having 342,711 households generating solid waste out of which 81,819 households dispose of their waste in public approved dumpsites while the remaining dispose of their household waste indiscriminately at unapproved dumpsites (Nigerian National Population Census, 2007). The state has a rural setting with her population predominantly farmers.

Kogi State is another north-central state of Nigeria considered for this study. The State has a total land mass of 29,833 km^2 with a population of about 1,869,377 people and a household of 641,556 generating solid waste out of which 124,313 households dispose of their waste in public approved dumpsites while the remaining households dispose of their waste in unapproved dumpsites (Nigerian National Population Census, 2007). The state also has a rural settlement with her population predominantly farmers.

The third state considers for this study is Niger which is located in the north central part of Nigeria. The state has a population of about 3,950,249 people with 729,964 households generating solid waste. A total of 200,078 household dispose of their waste in public approved dumpsites while 283,374 household disposes of their waste in unapproved dumpsite (National Population Census, 2006).

Table 1 Dumpsite study locations considered within the North Central part of Nigeria

S/No	State	Study Location	Coordinates		Elevation (M)
			Longitude (N)	Latitude (E)	
1	Kogi	Lokoja	7°51'24.64"	6°41'50.34"	149
		Kabba	7°49'54.85"	6°41'26.89"	447
		Okene	7°32'54.66"	6°14'28.71"	379
2	Nasarawa	Lafia	8°31'58.2"	8°31'43.32"	164
		Akwanga	8°54'31.16"	8°23'57.18"	464
		Nasarawa	8°32'12.45"	7°42'27.88"	190
3	Niger	Borgu	10°18'24.70"	4°15'5.49"	202
		Bida	9° 4'32.97"	6° 3'0.66"	180
		Minna	9°39'31.34"	6°25'1.93"	197

2.2 Equipment

During the course of this study, the following equipment's were used:

(i) Weighing balance: It was used for weighing the various soil samples.

(ii) Oven: Oven (model number: PBS118SF and serial number: 94L234) was used to dry the soil samples after 24 hours at 105°C.

(iii) Soil auger: It was used for collecting soil samples at various depths.

(iv) Atomic Absorption Spectrometer (AAS): It was used to determine cations, anions and trace metals in the Laboratory.

2.3 Sample and sampling techniques

The random method of sampling of the soils was used for the gathering of data around the dumpsite. A reference point of about 100 meters away from the point of sample collection on the dumpsite was also accessed. Samples were collected from three major towns in each of the states considering its Senatorial District. At each sample point, sample were collected at depths of 5, 15 and 30 cm to cover the root zone of most perennial crops after clearing off solid waste covering the natural soil as carried out by Nyangababo and Hamya (1986), Eddy et al. (2006) and Odai et al. (2008). This sampling method was also employed at the various reference points (RF). A total of nine samples were collected at each dumpsite and an overall total of 81 samples was collected for the whole study. Each of the samples collected was immediately placed in a fresh plastic labeled bag and tightly sealed. The collected soil samples were air–dried for seventy-two hours, ground in a mortar and passed through a 0.005 mm sieve and stored in clean acid treated polythene bags. The method employed by Tessier et al. (1979) for total metal analysis was used by digesting 1 g (<0.005 mm) of soil sample with a mixture of 5 mL HF and 1 mL $HClO_4$. The extract was analyzed using AAS.

2.4 Estimation of pollution index

The pollution level by a given heavy metal (*i*), is evaluated with the single pollution index (PI_i), and calculated as the ratio between the metal concentration (C_i) in a soil sample and its reference value (S_i) and interpreted using Table 2 as presented by Deng et al. (2012).

$$PI_i = \frac{C_i}{S_i} \tag{1}$$

Table 2 The evaluation grading standards of the single-factor pollution index

Sub Index	PI_i <1	1 ≥ PI_i >2	2 ≥ PI_i >3	PI_i ≥3
Quality grade	clean	Potential pollution	Slight pollution	Heavy pollution

2.5 Geo-accumulation index

The index of geo-accumulation (I_{geo}) introduced by Muller (1969) is used to assess metal pollution in a soil sample. It enables us to assess the level of contamination by comparing the concentrations at the dumpsite with the natural concentration at the reference point (Muller, 1969). Table 3 presents the grading standard of the geo-accumulation index. It can also be applied to assess the contamination of different environments. The index is calculated as follows:

$$I_{geo} = \log_2 \frac{C_n}{1.5 \times B_n} \tag{2}$$

where, C_n – Measured concentration of a metal in a soil sample; B_n – Measured concentration of a metal in control soil sample.

Table 3 The evaluation grading standards of the Geo-Accumulation Index

Sub Index	Quality grade
$I_{geo} \le 0$	Uncontaminated
$0 < I_{geo} \le 1$	Uncontaminated to moderately contaminate
$1 < I_{geo} \le 2$	Moderately contaminated
$2 < I_{geo} \le 3$	Moderately to heavily contaminated
$3 < I_{geo} \le 4$	Heavily contaminated
$4 < I_{geo} \le 5$	Heavily to extremely contaminated
$I_{geo} \ge 5$	Extremely contaminated

Factor 1.5 is used because of possible variations of the background data due to lithological variations. The world average shale and the world average soil are among the materials often used to provide background metal levels. The geochemical background values for the studied heavy metals are not available thus the concentration at control point is used as the background value for the naturally occurring metals in the study area.

2.6 Ecological risk assessment

This research employed the potential ecological risk index proposed by (Xu et al., 2015) to evaluate the potential ecological risk of heavy metals. This method comprehensively considers the synergy, toxic level, concentration of the heavy metals and ecological sensitivity of heavy metals (Nabholz, 1997; Singh et al., 2010; Douay et al., 2013). Potential ecological risk index is formed by three basic modules: degree of contamination (pollution Index (PI_i), toxic-response factor (T_{ri}) and potential ecological risk factor (*Eri*). Table 4 presents criteria for the degree of ecological risks.

$$E_{ri} = T_{ri} \times PI_i \quad (3)$$

Where

$$PI_i = C_i C_o \quad (4)$$

where, T_{ri} – Toxic-response factor for a given substance (i.e. Cu = 5, Cr = 2, Zn = 1); PI_i – Degree of contamination; C_i – Contamination factor (concentration in soil sample); C_o –Regional background value of heavy metals in the sediments (Reference point concentration).

Table 4 Criteria for degrees of ecological risk caused by heavy metals in sediments

Sub Index	Quality Grade
E_{ri}	Ecological pollution degree
$E_{ri} < 15$	Low ecological risk
$15 \le E_{ri} < 30$	Moderate ecological risk
$30 \le E_{ri} < 60$	Considerable ecological risk
$60 \le E_{ri} < 120$	high ecological risk
$E_{ri} \ge 120$	Very high ecological risk

The heavy metal content in the various soil samples collected from the dumpsite was compared with those of the respective reference point and European thresholds for agricultural soil. Regulatory standard for Agricultural soil in Nigeria was not available thus it was not presented, the difference in permissible limit across countries might be as a result of the natural abundance of the metals in the soil, the consumption pattern of individuals and the level of industrialization of individual countries.

3 Results and discussions

Results for Cu had a mean value of 19.33, 19.67 and 19.5 mg kg^{-1} in Lokoja, Kabba and Okene while 15.33, 44.00 and 37.33 mg kg^{-1} in Akwanga, Lafia and Nassarawa while Bida, New Bussa, and Minna had 33.67, 15.67, and 50.33 mg kg^{-1} respectively as presented in Table 5.

Table 5 Mean concentration (mg kg^{-1}) of heavy metals against reference points in selected

Metals	Sample point	Lokoja	Kabba	Okene	Lafia	Akwanga	Nasarawa	Borgu	Bida	Minna	Limit
Cr	Dumpsite	18.5	23.23	18.5	16.33	19.67	22	15.33	20	22	150
	Ref. Point	0.6	2.4	1.4	22	22.67	21.67	0.63	0.83	1.33	
Fe	Dumpsite	43	31	58	27.67	35	32	66	44	74	400
	Ref. Point	20	21	5.6	21	16	13	31.33	27	40.67	
Mn	Dumpsite	30.33	69	24.5	56	53.33	32	149	92.67	82.33	
	Ref. Point	12.67	45	7.7	16.67	17.67	21.67	23.33	27.67	33	
Zn	Dumpsite	20.67	25	35	51.67	43.33	29.67	20	23	20.33	450
	Ref. Point	12.67	2.15	28	8.67	24.33	18	0.67	1.53	2.1	
Cu	Dumpsite	19.33	19.67	24	15.33	44	37.33	33.67	15.67	50.33	200
	Ref. Point	18.33	13.5	22	15	15.33	25	0.7	0.53	1.7	
Al	Dumpsite	15.7	17.67	16.75	17.47	13	12	5.7	12.8	11.87	
	Ref. Point	10.23	10.2	11.5	12.37	12.47	13.37	11.03	11.37	16.37	

3.1 Soil Analysis

The determination of heavy metal in soil samples was done using energy Atomic Absorption Spectroscopy (AAS). Results show that Cr, Cu, Zn, Mn, Fe, and Al are present in the study area in low concentration, though the dumpsites show a higher concentration of these metals than the reference point which is 100 m away from the dumpsite. This difference indicated that the activities on the dumpsite are responsible for the presence of the metals in the soil of the dump site. Metal concentration and soil contamination vary across Kogi, Nasarawa and Niger States of Nigeria due to the difference in the nature of waste reaching the dumpsite. Table 5 shows the mean value for Cr, Fe, Mg, Zn, Cu and Al concentration on dumpsites of the various study locations. The result obtained indicates the presence of these metals which are within the permissible threshold for Agricultural soil (EU, 2000). A higher concentration of these metals was observed in the soil samples obtained from the dumpsites than the reference points.

3.2 The concentration of Copper in the study area

These values when compared with the recommended EU (2000) standard (200 mg kg^{-1}) for agricultural soil, it was observed to be within the recommended soil guideline value. From appendix I, the pollution index of 1.02, 1.05 and 1.09 for Lafia, Lokoja and Okene dumpsites also indicate that the dumpsite activities have not really added Cu to the soil at the reference point had concentrations of 15.00, 18.33 and 22.00 mg kg^{-1} which are slightly less than the concentration of the dumpsite of

15.33, 19.33 and 24.00 mg kg^{-1} as shown in Figure 1. This agrees with the work of Ediene and Umoetok (2017). Cu had a higher pollution index of 48.10, 29.57 and 29.41 in Borgu, Bida and Minna in dumpsites of Niger State. A similar result for the Copper concentration of 12.86 mg kg^{-1}, 21.08 mg kg^{-1} and 37.60 mg kg^{-1} was observed by Amadi and Nwankwoala (2013) in Enyimba dumpsite in Aba, Ebong and Ekong (2015) in dumpsites of Borokiri Town, Port Harcourt and Thomas (2015) in Ibadan Metropolis respectively. Borgu and Bida recorded a heavy geo-accumulation of copper thus there is the need for effective monitoring and possible reclamation to militate against its increase in the soil of the study area. Where Lkj is Lokoja, Kab is Kabba, Oke is Okene, LAF is Lafiya, AKW is Akwanga, NAS is Nassarawa, BOR is Borgu and MIN is Minna.

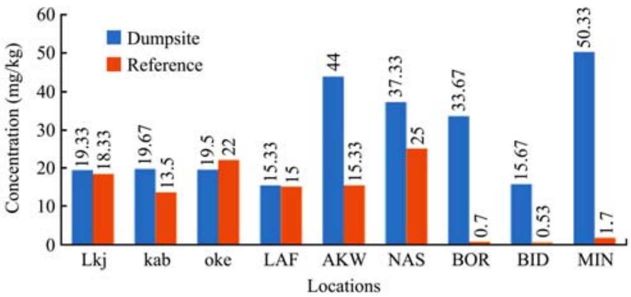

Figure 1 Concentration of copper against the reference point

3.3 Concentration of Chromium in the study area

The concentration of Cr at the various dumpsites of Kogi, Nasarawa and Niger States are presented in Figure 2. The abundance of this metal in these study locations were observed to be below the recommended threshold of EU (2000) Kabba dumpsite recorded the highest concentration (23.23 mg kg^{-1}) followed by Nasarawa, Minna and Bida with 22.00, 22.00 and 20.00 mg kg^{-1} respectively. Lafia and Akwanga dumpsite showed a peculiar condition where the concentration of heavy metals at the reference point was higher than those of the dumpsites considered these could be an indication of heavy metal migration or transfer through leachates and runoffs to bordering environs or a previous history where the reference points been used as dumpsites. Research by Anietie and Labunmi (2015) also presented a similar result where the gradual accumulation of Cr in municipal dumpsite of Akure was observed. The effect of this metal in the soil as shown in appendix II indicate that Lokoja, Kabba and Okene record a very high pollution index 30.83, 9.69 and 13.21 while 24.33, 24.10 and 16.54 for Borgu, Bida and Minna respectively which strongly indicate a high level of Cr pollution in the studied area.

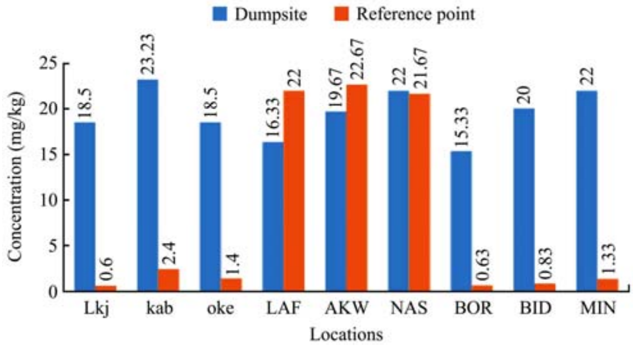

Figure 2 Concentration of chromium against a reference point

3.4 The concentration of Aluminum in the study area

The aluminum concentration at the various dumpsites was observed to be a little above those obtained from the reference points but below the permissible limit for the various study location. The pollution index of 1.53, 1.73, 1.46, 1.41, 1.04 and 1.12 for Lokoja, Kabba, Okene, Lafia, Akwanga and Bida respectively were observed. Nasarawa, Borgu, and Minna were observed to have higher values of Al concentration at the reference point than the dumpsite with a pollution index of 0.90, 0.52 and 0.73 respectively which indicates that the dumpsite soils were relatively not polluted when the obtained results were compared with the reference point concentration. The reference point concentration which represents the natural concentration of the metals is expected to be lower than that of the dumpsite as a result of the action of waste deposited on the site, which added heavy metals to the soil which already has same background value with the reference point. The low concentration of this metal in the study areas could be attributed to the migration of Al in a runoff to the surrounding environs thus increasing the concentration of Al at the reference point.

Results for the geological accumulation of the metals indicates that the soils range between not contaminated to moderately contaminated, as observed in appendix III. It can, therefore, be inferred that most of the materials dumped on the dumpsite do not contain materials that are rich in Aluminum. Aluminum is the third most common element found on the earth's crust. It exists in only one oxidation state (3^+) in the environment.

The main routes of aluminum consumption by humans are through inhalation, ingestion and dermal contact and sources of exposure are drinking water, food, beverages, and aluminum containing drugs. Aluminum is naturally present in food (Białowiec, 2011). Aluminum and its compounds are poorly absorbed in humans, although the rate at which they get absorbed has not been clearly studied (Jaishankar et al., 2014). Though no threat to life was observed form the concentration of Aluminum in the studied areas as it is still within the standard permissible limit of EU (2000).

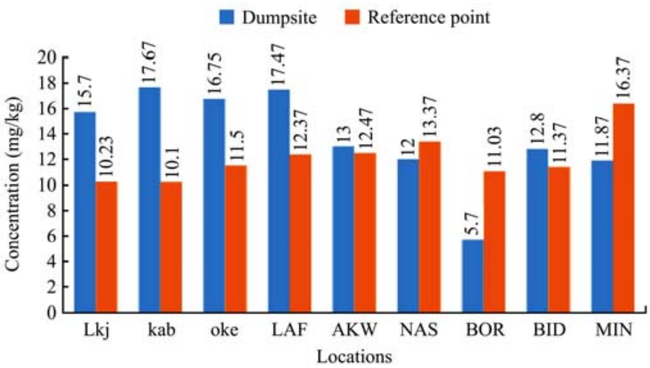

Figure 3 Concentration of aluminum against a reference point

3.5 Concentration of Iron in the study area

The concentration of Fe as shown in Figure 4 have a mean value of 43, and 58 mg kg^{-1} for Lokoja, Kabba and Okene while 27.67, 35 and 32 mg kg^{-1} in Akwanga, Lafia and Nasarawa while 66, 44 and 74 mg kg^{-1} Bida, Borgu and Minna respectively. These values were observed to be lower than the permissible threshold of which standard. The pollution index indicated that Kabba, Bida, and Lafia has a high Fe content in the soils of the study areas while study areas of Lokoja, Akwanga, Nasarawa, and Borgu indicated slight high pollution while Okene recorded heavy pollution. These concentrations of Fe could be as a result of the types and volume of refuse dumped and the duration of which the dumpsite has been in use. Fe pollution in Okene can also be associated with mining of Iron ore in the metropolis. Lokoja and Okene have abundant iron and other mineral resources thus the high Fe content. The observed values obtained for the various study locations is not any different from that observed by Shaibu et al. (2015) for dumpsites in Ilorin.

They stated that the high content of Fe within the dumpsites was linked to the nature and size of the waste and also regular burning of the waste at the dumpsite that impacts on the metal concentration at the dumpsite as shown in Appendix IV. This was observed not to be different for the various dumpsites of the study locations. Iron is the most abundant metal in the earth's crust with soil level ranging from 7 to 550 g kg^{-1}. The daily intake of iron in diets ranges between 9-35 mg. This varies from location to location as it depends on the source of the diet and agricultural products within the area. Areas, where mining is common, contains higher iron contents. Iron is an essential element for growth and survival of almost all living organisms (Valko et al., 2005) its oxygen-transporting proteins, such as hemoglobin and myoglobin makes it vital (Vuori, 1995). Iron-mediated reactions support most of the aerobic organisms in their respiration process (Jaishankar et al., 2014). They further stated that excess accumulation of iron in the body can damage biomolecules, cells, tissues and the whole organism, Iron can initiate cancer mainly by the process of oxidation of DNA molecules (Bhasin et al., 2002).

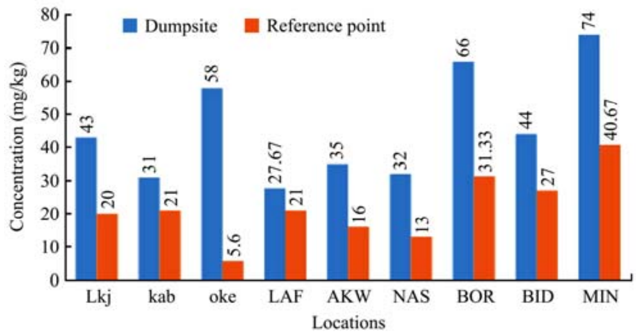

Figure 4 Concentration of iron against a reference point

3.6 Concentration of Manganese in the study area

The presence of Mn in all the dumpsites is presented in Figure 5. It was observed that all the values were below the permissible limits. Soils within the various dumpsites have a varying amount of Mn content with Borgu recording the highest value of 149 mg kg^{-1} with a pollution index of 6.38, Bida had 3.34 mg kg^{-1} and Minna with 2.34 mg kg^{-1}. The concentration of Mn at Kabba was determined to be 69.00 mg kg^{-1} thus making it the lowest when compared to those observed at Borgu. Kabba had the highest pollution index of 15.33 and the soil is exposed to moderate ecological risk as indicated in appendix V. Figure 5 shows that there is an abundance of the natural occurrence of Manganese in Niger than in Kogi and Nasarawa States. The various materials that are consumed by the populace in Niger may account for the high content of Mn. Mn compounds exist naturally in the environment as solids in the soils and small particles in the water. It serves as an activator for enzymes in growth processes and assists iron in chlorophyll formation. Manganese is one of three toxic essential trace elements, which means that it is not only necessary for humans to survive, but it is also toxic when consumed in high concentrations by humans. Excess exposure to this metal can cause damage to the respiratory tract and the brain.

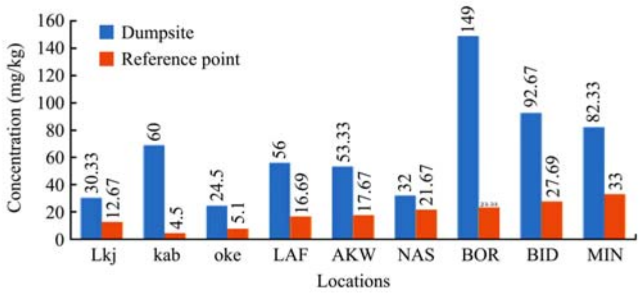

Figure 5 Concentration of manganese against a reference point

3.7 Concentration of Zinc in the study area

Zinc was found to be present in all the studied dumpsite though within the standard limit 450 mg kg^{-1}. Figure 6 shows that Lokoja, Okene, Nasarawa and Akwanga show an abundance of naturally occurring Zinc at the reference point with Lafia recording the highest value 51.67 mg kg^{-1} followed by Akwanga with a value of 43.33 mg kg^{-1} and Okene recording 35.00 mg kg^{-1}. This is could be linked to the geological formation of the various study area. A similar result on the concentration of Zinc in soils of dumpsite was observed by Adefemi and Awokunmi (2009) during a study carried out on the impact of municipal solid waste disposal in Ado- Ekiti metropolis, Ekiti-State. Okene, Lokoja, Nasarawa, Akwanga indicates potential pollution with a pollution index of 1.25, 1.63, 1.65, and 1.78 respectively while Lafia, Minna, Kabba, Bida, and Borgu recorded heavy pollution with a pollution index of 5.96, 9.68, 11.63, 15.03 and 29.85 respectively as shown in Appendix VI. The geological accumulation of Zinc in Lokoja, Okene, Nasarawa, Akwanga, and Lafia is not yet treating as the sites are either currently moderately contaminated, Kabba, Bida, and Minna showed a moderate geo-accumulation of Zinc in the soil of the dumpsites, more worrisome is the accumulation in Borgu analysis shows that there is a heavy geological accumulation of Zinc in the soil of the dumpsite. The level of this metal in the soil require immediate attention to remedy the soil. The ecological risk index for Borgu and Bida shows moderate ecological risk which implies that the level of zinc accumulation in the soil from the activities of the dumpsite has not adversely polluted to the soil as at present but in the nearest future it may be. While Lokoja, Okene, Nasarawa, Akwanga, Kabba, Minna, and Lafia indicates low ecological risk.

Compared to several other metal ions with similar chemical properties, zinc is relatively harmless. Though its exposure to a high dose has been established to have toxic effects, making it an acute zinc intoxication a rare event. Water is polluted with zinc, due to the presence of large quantities of zinc in leachates from dumpsites. Water-soluble zinc that is located in soils can contaminate groundwater.

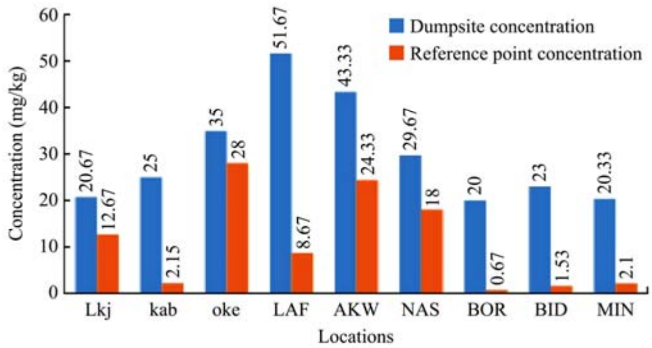

Figure 6 Concentration of zinc against a reference point

4 Conclusion

The study showed that all the dumpsite contained Al, Cu, Cr, Mn, Fe, and Zn. It was also observed that some dumpsites had a higher concentration of these metals than others; this could be attributed to the presence of waste carrying higher amounts of these heavy metals and the geological formation of the areas. The dumpsites were observed not to pose any threat to human health at the moment since the concentration of these metals is within the WHO acceptable limit. However, the pollution index, geo-accumulation index and ecological risk assessment of these metals in the soil indicate the possibility of an ecological threat. The extent of heavy metal pollution in the studied is very high and this can be associated with the increasing growth of the urban centers which in turn increases the amount of waste generated and disposed of. The planting of edible fruits and other agricultural products on dumpsite is an unhealthy practice thus the consumption of such food products contribute to health hazards. Farming activities around the dumpsite should be discouraged as the farm products are prone to take up these metals. Remediation of Cu is necessary for Borgu, Bida and Minna dumpsite as the results show the highest pollution index 48.10, 29.57 and 29.41 respectively with a very high ecological risk index. Likewise, remediation of Cr is necessary for Lokoja, Kabba Okene, Borgu, Bida and Minna dumpsite as the metal poses an ecological threat on the dumpsite. Also, remediation of Zn is necessary for Borgu dumpsite as result shows moderate ecological risk which implies that the level of zinc accumulation in the soil is significantly higher than the background.

Acknowledgments

The authors are grateful to the Federal University of Technology Minna and Tertiary Education Trust Fund for providing grants to carry out this research work. They are also thankful to laboratory staff of Soil Science Department, Federal University of Technology Minna, Niger State, and Chemistry Department Ahmadu Bello University Zaria, Nigeria who assisted in carrying out soil analyses.

References

Abdus-Salam, N., M. S. Ibrahim, and F. T. Fatoyinbo. 2011. Dumpsites in Lokoja, Nigeria: A silent pollution zone for underground water. *Waste Management and Bioresource Technology*, 1: 21–30.

Adefemi, S.O., and E. E. Awokunmi. 2009. The impact of municipal solid waste disposal in Ado- Ekiti metropolis, Ekiti-State, Nigeria. *Science and Technology*, 3(8): 186–189.

Amadi, A. N., and H. O. Nwankwoala. 2013. Evaluation of heavy metal in soils from Enyimba dumpsite in Aba, southeastern Nigeria using contamination factor and geo-accumulation index. *Energy and Environment Research*, 3(1): 125–134.

Anietie, O. V., and L. Labunmi. 2015. Surface soil pollution by heavy metals: a case study of two refuse dumpsites in Akure metropolis. *International Journal of Scientific and Technology Research*, 4(03): 71–74.

Aydi, A. 2015. Assessment of heavy metal contamination risk in soils of landfill of Bizerte (Tunisia) with a focus on application of pollution indicators. *Environmental Earth Sciences*, 74(4): 3019–3027.

Bhasin, G., H. Kauser, and M. Athar. 2002. Iron augments stage-I and stage-II tumor promotion in murine skin. *Cancer Letters*, 183(2): 113–122.

Białowiec, A. 2011. Hazardous emissions from municipal solid waste landfills. *Contemporary Problems of Management and Environmental Protection*, 9: 7–28.

Deng, G., F. Gu, Li. H, and X. Deng. 2012. Comprehensive assessment model on heavy metal pollution in soil. *International Journal of Electrochemical Science*, 7(6): 5286–5296.

Douay, F., A. Pelfrêne, J. Planque, H. Fourrier, A. Richard, H. Roussel, and B. Girondelot. 2013. Assessment of potential health risk for inhabitants living near a former lead smelter, Part 1: metal concentrations in soils, agricultural crops, and home-grown vegetables. *Environmental Monitoring and Assessment*, 185(5): 3665–3680.

Duffus, J. H. 2002. Heavy metals a meaningless term (IUPAC Technical Report). *Pure and Applied Chemistry*, 74(5): 793–807.

Ediene, V. F., and S. B. A. Umoetok. 2017. Concentration of heavy metals in soils at the municipal dumpsite in Calabar metropolis. *Asian Journal of Environment and Ecology*, 3(2): 1–11.

Ebong, G. A., and C. I. Ekong. 2015. Pollution status of trace metals in waste impacted soils within Borokiri town, Port Harcourt metropolis, Rivers State, Nigeria. *International Journal of Scientific Research in Environmental Sciences*, 3(12): 0436–0444.

Eddy, N. O., S. A. Odoemelem, and A. Mbaba. 2006. Elemental composition of soil in some dumpsites. *Journal of Environmental Agricultural Food Chemistry*, 5(3): 1349–1365.

Eriyamremu, G. E., S. O. Asagba, A. Akpoborie, and S. I. Ojeaburu. 2005. Evaluation of lead and cadmium levels in some commonly consumed vegetables in the Niger-Delta oil area of Nigeria. *Bulletin of Environmental Contamination and Toxicology*, 75(2): 278–283.

EU. European Union Directive. 2000. 86/278/EEC. Third draft working document on sludge (ENV.E.3/LM). Brussels: EU.

Jaishankar, M., T. Tseten, N. Anbalagan, B. B. Mathew, and K. N. Beeregowda. 2014. Toxicity, mechanism and health effects of some heavy metals. *Interdisciplinary Toxicology*, 7(2): 60–72.

Lawson, E. O. 2011. Physico-chemical parameters and heavy metal contents of water from the Mangrove Swamps of Lagos Lagoon, Lagos, Nigeria. *Advances in Biological Research*, 5(1): 08–21.

Lee, C. S. L., X. Li, W. Shi, S. Cheung, and I. Thornton. 2006. Metal contamination in urban, sub-urban, and country park soils of Hong Kong: a study based on GIS and multivariate statistics. *Science of the Total Environment*, 356(1-3): 45–61.

Lenntech, 2009. Iron in groundwater, Lenntech watertreatment and purification holding B.V,Rotterdamseweg, Netherlands. http://www.lenntech.com/who-eu-water-standards.htm

Muchuweti, M., J. W. Birkett, E. Chinyanga, R. Zvauya, M. D.

Scrimshaw, and J. N. Lester. 2006. Heavy metal content of vegetables irrigated with mixture of waste water and sewage sludge in Zimbabwe: implications for human health. *Agriculture, Ecosystem and Environment*, 112(1): 41–48.

Mudgal, V., N. Madaan, A. Mudgal, R. B. Singh, and S. Mishra. 2010. Effect of toxic metals on human health. *The Open Nutraceutical Journal,* 3(1): 94–99.

Muller, G. 1969. Index of geoaccumulation in sediments of the Rhine River. *Geo Journal*, 2: 108–118.

Nabholz, J. V. 1997. Environmental hazard and risk assessment under the United States Toxic substances control act. *Science of Total Environment*, 109/110: 649–665.

Nigerian National Population Commission (2007): Report of Nigeria's National Population Commission on the 2006 Census. *Population and Development Review* Vol. 33, No. 1, pp. 206–210.

Nyangababo, J. T., and J. W. Hamya. 1986. The deposition of lead, cadmium, zinc and copper from motor traffic on Brachiaria enimi and soil along a major Bombo road in Kampala city. *International Journal Environmental Studies*, 27(1-2): 115–119.

Odai, S. N., E. Mensah, D. Sipitey, S. Ryo, and E. Awuah. 2008. Heavy metals uptake by vegetables cultivated on urban waste dumpsites: Case study of Kumasi, Ghana. *Research Journal of Environmental Toxicology*, 2(2): 92–99.

Oguzie, E. E., I. B. Agochukwu, A. I. Onuchukwu, and J. O. Offem. 2002. Groundwater contamination: A simulation study of buried waste metallic contaminant penetration through the aquifers. *Journal of the Chemical Society of Nigeria*, 27: 82–84.

Koki, I., and W. L. O. Jimoh. 2013. Determination of heavy metals in soils from dump site of tanneries and farmlands in Challawa Industrial Estate Kano, Nigeria. *Bayero Journal of Pure and Applied Sciences*, 6(2): 57–64.

Razo, I., L. Carrizales, and J. Castro. 2004. Arsenic and heavy metal pollution of soil, water and sediments in a semi-arid climate mining area in Mexico. *Water Air and Soil Pollution*, 152(1-4): 129–152.

Remon, E., J. L. Bouchardon, B. Cornier, B. Guy, J. C. Leclerc, and O. Faure. 2005. Soil characteristics, heavy metal availability and vegetation recovery at a former metallurgical landfill: Implications in risk assessment and site restoration. *Journal by Elsevier on Environmental Pollution*, 137(2): 316–323.

Sabri, A., F. Islam, T. Ahmet, R. Mursel, and H. Muhamedin. 2013. Assessment of heavy metal in the water springs, Stan Terg, Kosovo. *International Journal of Engineering and Applied Sciences,* 2(4): 53–60.

Satarug, S., M. R. Haswell-Elkins, and M. R. Moore. 2000. Safe levels of cadmium intake to prevent renal toxicity of human subjects. *British Journal of Nutrition*, 84(6): 791–802.

Shaibu, S. E., F. A. Adekola, H. T. Adegoke, and N. Abdus-Salam. 2015. Heavy metal speciation patterns of selected dumpsites in Ilorin Metropolis. *International Journal of Chemical, Material and Environmental Research*, 2(1): 1–11.

Shittu, O. S., O. J. Ayodele, A. O. Ilori, A. O. Filani, and A. T. Afuye. 2017. Heavy metal contamination of a dumpsite environment as assessed with pollution indices. *International Journal of Biological, Biomolecular, Agricultural, Food and Biotechnological Engineering*, 12(1): 1–7.

Singh, A., R. K. Sharma, M. Agrawal, and F. M. Marshall. 2010. Health risk assessment of heavy metals via dietary intake of foodstuffs from the wastewater irrigated site of a dry tropical area of India. *Food Chemistry and Toxicology*, 48(2): 611–619.

Speir, T. W., A. P. Van. Schaik, H. J. Percival, M. E. Close, and L. P. Pang.2003. Heavy metals in soil, plants and groundwater following high-rate sewage sludge application to land. *Water, Air, and Soil Pollution,* 150(1-4): 319–358.

Tessier, A., P. G. C. Campell, and M. Bisson. 1979. Sequential extraction procedure for the speciation of particulate trace. *Analytical Chemistry,* 51(7): 844–851.

Thomas, E. Y. 2015. Assessment of heavy metal concentration and fractionation in selected dumpsite soils within Ibadan metropolis, Nigeria. *Journal of Agriculture and Ecology Research International*, 4(3): 117–127.

Valko, M., H. Morris, and M. T. D. Cronin. 2005. Metals, toxicity and oxidative stress. *Current Medical Chemistry*, 12(10): 1161–1208

Vidal, M., J. Melgar, A. Lopez, and M. C. Santoalla. 2000. Spatial and temporal hydrochemical changes in groundwater under the contaminating effects of fertilizers and wastewater. *Journal of Environmental Management*, 60(3): 215–225

Vuori, K. M. 1995. Direct and Indirect effects of iron on river ecosystems. *Annales Zoologici Fennici*, 32(3): 317–329.

Xu, X., X. Lu, X. Han, and N. Zhao. 2015. Ecological and health risk assessment of metal in resuspended particles of urban street dust from an industrial city in China. *Current Science*, 108(1): 72–79.

Zaini, S., A. Mustapha, and F. M. J. Mohd. 2013. Possibility of heavy metals contaminated solid waste from municipal waste disposal sites in Pangkor Island Perak State, Malaysia. *Research Journal of Applied Science*, 8(1): 14–21.

APPENDIX I

Concentration of Copper against reference point

Parameter	Lokoja	Kabba	Okene	Lafia	Akwanga	Nasarawa	Borgu	Bida	Minna
Pollution Index	1.05	1.46	1.09	1.02	2.87	1.49	48.10	29.57	29.41
	potential pollution	potential pollution	potential pollution	potential pollution	slightly pollution	potential pollution	heavily pollution	heavily pollution	heavily pollution
Geo accumulation Index	0.16	0.21	0.13	0.18	0.24	0.14	4.83	4.99	2.22
	uncontaminated to moderately contaminated	uncontaminated to moderately contaminated	uncontaminated to moderately contaminated	uncontaminated to moderately contaminated	uncontaminated to moderately contaminated	uncontaminated to moderately contaminated	heavily to extremely contaminated	heavily to extremely contaminated	moderately contaminated
Ecological Risk Index	5.25	7.3	5.45	5.1	14.35	7.49	240.5	147.8	147.05
	Low ecological risk	Low ecological risk	Low ecological risk	Low ecological risk	Low ecological risk	Low ecological risk	Very High ecological risk	Very High ecological risk	Very High ecological risk

APPENDIX II

Impact of Chromium on the selected dumpsites

Parameter	Lokoja	Kabba	Okene	Lafia	Akwanga	Nasarawa	Borgu	Bida	Minna
Pollution Index	30.83	9.69	13.21	0.74	0.87	1.02	24.33	24.10	16.54
	Heavily polluted	Heavily polluted	Heavily polluted	Clean	Clean	Potential pollution	Heavily polluted	Heavily polluted	Heavily polluted
Geo accumulation Index	4.68	2.00	1.26	0.12	0.13	0.14	4.17	3.47	2.24
	heavily to extremely contaminated	moderately contaminated	moderately contaminated	uncontaminated to moderately contaminated	uncontaminated to moderately contaminated	uncontaminated to moderately contaminated	heavily to extremely contaminated	heavily contaminated	moderately to heavily contaminated
Ecological Risk Index	61.66	19.38	26.42	1.48	1.74	2.04	48.66	48.2	33.08
	High ecological risk	Moderate ecological risk	Moderate ecological risk	Low ecological risk	Low ecological risk	Low ecological risk	Considerable ecological risk	Considerable ecological risk	Considerable ecological risk

APPENDIX III

Impact of Aluminium concentration on the studied area

Parameter	Lokoja	Kabba	Okene	Lafia	Akwanga	Nasarawa	Borgu	Bida	Minna
Pollution Index	1.53	1.73	1.46	1.41	1.04	0.90	0.52	1.12	0.73
	Potential pollution	Potential pollution	Potential pollution	Potential pollution	Potential pollution	Clean	Clean	Potential pollution	Clean
Geo-accumulation Index	0.26	0.27	0.24	0.22	0.20	0.18	0.15	0.22	0.15
	uncontaminated to moderately contaminated	uncontaminated to moderately contaminated	uncontaminated to moderately contaminated	uncontaminated to moderately contaminated	uncontaminated to moderately contaminated	uncontaminated to moderately contaminated	uncontaminated to moderately contaminated	uncontaminated to moderately contaminated	uncontaminated to moderately contaminated

APPENDIX IV

Impact of Iron Concentration on the studied area

Parameter	Lokoja	Kabba	Okene	Lafia	Akwanga	Nasarawa	Borgu	Bida	Minna
Pollution Index	2.15	1.48	10.36	1.32	2.14	2.43	2.11	1.63	1.87
	slightly polluted	potential polluted	heavily polluted	potential polluted	slightly polluted	slightly polluted	slightly polluted	potential polluted	potential polluted
Geo-accumulation Index	0.18	0.16	0.70	0.15	0.21	0.25	0.13	0.13	0.10
	uncontaminated to moderately contaminated	uncontaminated to moderately contaminated	uncontaminated to moderately contaminated	uncontaminated to moderately contaminated	uncontaminated to moderately contaminated	uncontaminated to moderately contaminated	uncontaminated to moderately contaminated	uncontaminated to moderately contaminated	uncontaminated to moderately contaminated

APPENDIX V

Impact of Manganese Concentration in the studied area.

Parameter	Lokoja	Kabba	Okene	Lafia	Akwanga	Nasarawa	Borgu	Bida	Minna
Pollution Index	2.39 slightly polluted	15.33 heavily polluted	3.18 heavily polluted	3.36 heavily polluted	3.02 heavily polluted	1.48 potential polluted	6.38 heavily polluted	3.34 heavily polluted	2.49 slightly polluted
Geo-accumulation Index	0.26 uncontaminated to moderately contaminated	0.90 uncontaminated to moderately contaminate	0.40 uncontaminated to moderately contaminated	0.23 uncontaminated to moderately contaminated	0.22 uncontaminated to moderately contaminated	0.15 uncontaminated to moderately contaminated	0.21 uncontaminated to moderately contaminated	0.16 uncontaminated to moderately contaminated	0.13 uncontaminated to moderately contaminated
Ecological Risk Index	2.39 Low ecological risk	15.33 Moderate ecological risk	3.18 Low ecological risk	3.36 Low ecological risk	3.02 Low ecological risk	1.48 Low ecological risk	6.38 Low ecological risk	3.34 Low ecological risk	2.49 Low ecological risk

APPENDIX VI

Impact of Zinc Concentration on the studied area

Parameter	Lokoja	Kabba	Okene	Lafia	Akwanga	Nasarawa	Borgu	Bida	Minna
Pollution Index	1.63 Potential pollution	11.63 heavily pollution	1.25 Potential pollution	5.96 heavily pollution	1.78 Potential pollution	1.65 Potential pollution	29.85 heavily pollution	15.03 heavily pollution	9.68 heavily pollution
Geo-accumulation Index	0.23 uncontaminated to moderately contaminated	1.44 moderately contaminated	0.12 uncontaminated to moderately contaminated	0.44 uncontaminated to moderately contaminated	0.15 uncontaminated to moderately contaminated	0.18 uncontaminated to moderately contaminated	4.30 heavily to extremely contaminated	1.97 moderately contaminated	1.38 moderately contaminated
Ecological Risk Index	1.63 Low ecological risk	11.63 Low ecological risk	1.25 Low ecological risk	5.96 Low ecological risk	1.78 Low ecological risk	1.65 Low ecological risk	29.85 Moderate ecological risk	15.03 Moderate ecological risk	9.68 Low ecological risk