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Evaluation of Heavy metals pollution around Kano municipal solid waste Dumpsites, Kano state, Nigeria

MZ Karkarna and Mujahid Ajah Matazu
Department of Environmental Management, Bayero University P.M.B 3011-Kano
Correspondence authors: mzkarkarna@ gmail.com

Abstract
The research was conducted to assess the level of heavy metals contamination using single and integrated pollution indices in soils around municipal solid waste dumpsites of Kano Metropolis, Kano State, Nigeria. Forty two soil samples were collected from seven municipal solid waste dumpsites of Kano metropolis using circular plot method. A stainless hand auger at a depth of (0 to 15) top soils and sub-surface soils (15-30cm) depth were collected and analyzed with Flame atomic absorption spectrophotometer to determine the heavy metal concentration. The mean concentration (mg/kg) of heavy metals from the depth of (15-30 cm) were observed to follow a decreasing order Pb (7.71)>Zn (0.50) > Ni (0.45) > Cr (0.31) > Cd (0.025) while for surface soils (0-15cm) the mean concentration were in the following order: Pb (1.77) > Ni (0.49) > Zn (0.30) > Cr (0.27) > Cd (0.012).The results showed that calculated CF and Er recorded that investigated soil samples are uncontaminated with Zn, Pb, Cd, Cr and Pb and Ni. The pollution load index (PLI) was less than unity showing that there was minimum pollution in the studied dumpsite. The potential ecological risk showed that soil samples were in the class of low contaminated with the studied heavy metals. The results showed that concentrations of heavy metals of soil samples from dumpsites location at waste dumpsites of Kano Metropolis were within limits of European Union (2002) standards.
Keywords: Heavy metals, single and integrated pollution indices Kano, Municipal dumpsites,

INTRODUCTION

Solid wastes disposal in major cities of Nigeria in the last few decades has posed major environmental and public health problems (Dirisu *et al,* 2019). Most affected are those living adjacent the dumpsites due to the potential of the waste to pollute water, food sources, land, air and vegetation (Un-habitat, 2008). In Kano Metropolis and most developing cities in Africa where increase in population and industrial activities were being experienced mostly due urbanization and economic development, has led to indiscriminate dumping of wastes of various sources in and around any available large expanse of land either under fallow or abandoned by the land owners. Research carried out on lands close to dumpsites at Zaria city showed that soil around dumpsites is as well contaminated with heavy metals (Olayiwola *et al.,* 2017).

Pollution indices are a powerful tool for environmental quality assessment. The commonly used pollution indices for heavy metals in soils are classified into two types, single and integrated pollution index (Yuan *et al.*, 2004, Qingjie *et al.*, 2008; Hafizur Rahman *et al.*, 2012). In the present study, two single indices, namely index of contamination factor (CF) and ecological risk factor (Er), as well as two integrated indices potential ecological risk index (PRI) and pollution load index were used to evaluate the level of heavy metal pollution around Kano municipal solid waste dumpsite. There have been a number of studies which reported the physico-chemical characteristics and concentration of heavy metals in soil around the vicinity of dumpsites in Kano Metropolis (Karkarna and Mujahid, 2020, Ali, 2017, Koki and Jimoh, 2013 and Sabo and Jimoh, 2013). But, none of the studies attempt to evaluate the level of heavy metal pollution using single and integrated pollution index. Therefore the objectives of the present study were (1) to determine contents of Zn, Pb, Cd, Cr and Ni in soils of municipal solid waste dumpsites; (2) to determine the level of heavy metals pollution using single indices (contamination factor and ecological risk factor and integrated pollution indices which include (potential ecological risk index (PERI) and pollution load index (PLI).

MATERIALS AND METHODS

Study Area

The metropolitan city of Kano is the largest urban setting in northern Nigeria and only second to Lagos in the whole country. It is known for a wide range of industrial and commercial activities (Maconachie, 2007). It consists of 8 local government areas with a total population of approximately 4 million. The metropolis spreads across an area of about 500km2 located between longitude 8^0 and 9^0 east and latitude 10^0 and 12^0 north (Ahmed *et al.,* 2013). Kano falls within the Sudan savannah vegetation zone enjoying the warm tropical climatic condition of Western Africa. It is positioned in the northern central boundary of Nigeria at about 840km away from the beginning of Sahara desert and about 1,140km away from the coast of Atlantic Ocean (Okunola *et al*., 2012)

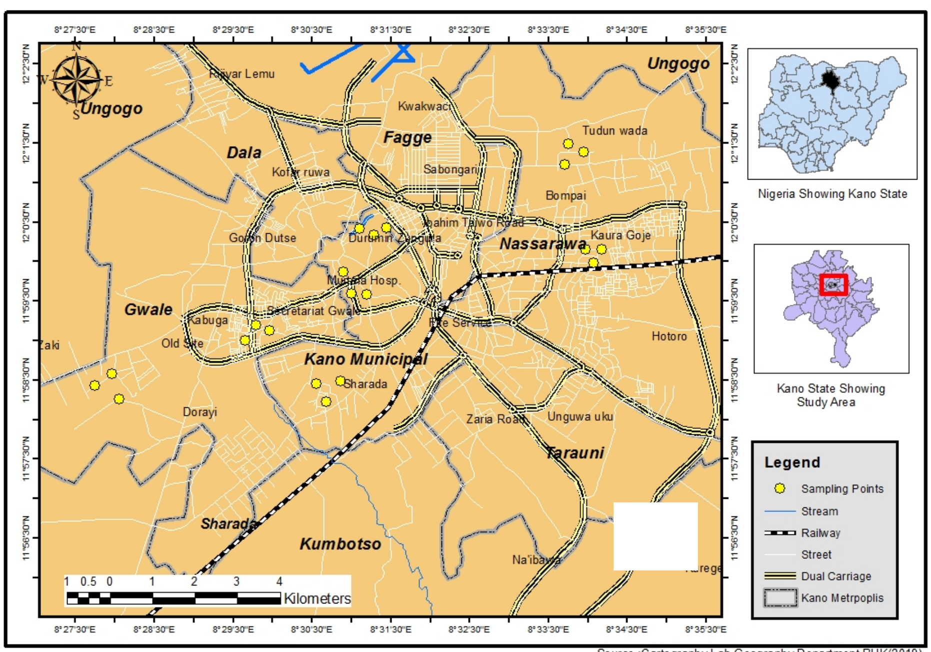
The research instruments used include GPS for recording the coordinate, soil auger used for taking the soil sample, measuring tape used for measuring the soil depth, Kjiedal digestion set apparatus and Atomic absorption spectrophotometer were used to analyze the concentration of heavy metals under investigation

Soil Collection and Sampling

Forty two soil samples were collected from seven municipal solid waste dumpsites of Kano metropolis using circular plot method. In each dumpsite, three point's soil samples were collected from the depth (S1, S2 and S3). At each point, two soil samples were collected from the depth of 0-15cm and 15-30cm. Each soil sample was composed of 2 sub-samples collected around the corresponding sampling point, and all the sampling coordinates were recorded by portable GPS. The samples were carefully handled right from the field to the end of the laboratory analysis to avoid contamination. Figure 1 shows soil sampling points in each of the seven dumpsites

Soil Preparation and Analysis

The soils were air dried for three days, ground and sieved through a 2 mm sieve. These were stored in labelled polythene bags and were taken to the laboratory for analysis. After which, 1.25 g of each sample was digested with 20 mL aqua regia (HCl/HNO_3 3:1) in a beaker (open-beaker digestion) on a thermostatically controlled hot plate. The digest were heated to near dryness and cooled to ambient temperature. Then 5.0 mL of hydrogen peroxide was added in parts to complete the digestion and the resulting mixture heated again to near dryness in a fume cupboard. The beaker walls were washed with 10 mL of de-ionised water and 5 mL HCl were added, mixed and heated again. The resulting digest was allowed to cool and transferred into a 50 mL standard flask and made up to the mark with de-ionised water. Pb, Cd, Ni, Zn, and Cr heavy metal elements were then analyzed by direct aspiration of the sample solution into a Perkin-Elmer model 2380 flame atomic absorption spectrophotometer (AAS).



Source :Cartography Lab Geography Department BUK(2019)

Figure Figue1: View of Kano Metropolis Showing the Sampling Locations

STATISTICAL ANALYSIS

Data were analyzed using SPSS software (version 23) and micro soft Excel 2007. Descriptive statistics were conducted to determine the mean of investigated heavy metals in soil samples. The single pollution indices (contamination factor and ecological risk) and integrated pollution index (PLI and potential ecological risk) were analyzed using descriptive statistics in which data were presented in mean and table.

Assessment of heavy metals pollution

In this study, the assessment of soil pollution was conducted using the two single indices, namely index of contamination factor (CF) and ecological risk factor (Er), as well as two integrated indices such as pollution load indices and potential ecological risk index (PRI).

SINGLE INDICES POLLUTION

1. **Contamination Factor** (Cf) is the ratio of the concentration of each metal (Ci) to the background or reference value (Cri). Where Ci is the mean concentration of each of the investigated metal in soil or sediment drawn from at least five sampling sites and Cri is the background value of the metal. In order to unify the assessment results, reference values as provided by Department of Petroleum Resources threshold value (DPR) 2002 were used as background values (Cr = 100, Ni = 35, Zn =140, Cd = 0.88 and Pb = 85). The following terminology was used for the pollution index model: PI < 1, non-pollution; 1 ≤ PI < 2, low level pollution; 2 ≤ PI < 3, moderate level of pollution; 3 ≤ PI < 5, strong level of pollution; PI ≥ 5, very strong level of pollution (Yang *et al.*, 2011).
2. **Ecological risk index (Er):-**This is an index that quantitatively expresses the potential ecological risk associated with a given single contaminant Hakanson (1980). Calculated as follows:

   Er = Tf x Cf………………… (Equation 1);

   Where,Tf is the toxic-response factor of an element, and Cf is the contamination factor. Five terminologies are used to define ecological risks based on Hakanson (1980). These are < 40, low potential ecological risk; 40 < 80, moderate potential ecological risk; 80 < 160, considerable potential ecological risk; 160 < 320, high potential ecological risk; and ≥ 320, very high ecological risk.

Table 1 Toxic Response factor for studied heavy Metals (Zn, Pb, Cd, Cr and Ni)

S/No.	Element	Toxic Response Factor
1	Zinc	1.0
2	Lead	5.0
3	Cadmium	30
4	Chromium	2.0
5	Nickel	5.0

Adopted by Hakanson (1980)

INTEGRATED POLLUTION INDICES

1. **Potential ecological risk index (PERI)**

Potential ecological risk index (PERI):-This index is the sum of all the ecological risk factors of the metals under study, taking into account the cumulative effects of the metals under study (Hakanson, 1980). It is calculated thus:

$\sum R$I = (ErF1 + ErF2 + ErF3…+ErFn)……………………Equation

Where, ErF is the ecological risk factor and n is the number of elements studied.

The following terminologies have been used for the potential ecological risk index (Hakanson, 1980): < 150, low ecological risk; 150 < 300, moderate ecological risk; 300 < 600, considerable ecological risk; and ≥ 600, very high ecological risk. This method comprehensively considers the synergy, toxic level, concentration of the heavy metals and ecological sensitivity of heavy metals. PERI is formed by three basic modules: degree of contamination (Cd), toxic-response factor (Tr) and ecological risk factor (Er) (Jiang, 2014).

2. **Pollution load index**

The number of times the metal concentration in the sampled soil exceeded the average natural background concentration is indicated by the PLI value and it reveals the total comprehensive degree of heavy metal toxicity in a given sample (Ololade, 2014).Pollution load index is an example of root of the product of pollution index indices which is based on contamination factor of each metal in soil. This aspect of integrated pollution indices have been used to quantify pollution load of heavy metals in both soils and sediments.

The model also provides an easy and comprehensive means of assessing the quality of an investigated site (Waheshi *et al.*, 2017; Goher *et al.*, 2014). Where PLI is pollution load index of individual metal described earlier and n is the number of investigated metals.

$$PLI=\sqrt{CF1 \times CF2 \times CF3 \ldots\ldots\ldots CFn}^{1/n} \quad \text{...Equation}$$

RESULTS AND DISCUSSION

The mean concentrations of heavy metals in the soil samples are shown in Table 2. The data revealed that all the analyzed metals accumulated by the soil in two different depth of top soil (0-15 cm) and sub soil (15-30) cm.

Table 2 Mean Concentration of Heavy Metals in Comparison with EU and DPR (2002) Standard

Element	Top soil (0-15) cm	Sub-surface (15-30) cm	EU (2002) Standard.	D.P.R(2002) Standard
Zn	0.30	0.50	300	140
Pb	1.71	7.71	300	85
Cd	0.012	0.025	3.0	0.88
Cr	0.27	0.31	100	100
Ni	0.49	0.45	75	35

Sources: Laboratory Analysis (2019) and EU and DPR (2002) Standard

The mean concentration of zinc (Zn) was in the range of 0.30–0.50 mg/kg. The lowest zinc content (0.30 mg/kg) was obtained at (0-15cm) depth and the highest (0.50 mg/kg) was recorded from the depth (15-30cm). The results of this study were slightly lower as compared to a study by Lawan *et al.*, (2012) on vertical migration of heavy metals in dumpsite soil at Maiduguri Metropolis dumpsite, Nigeria that reported mean zinc concentration at 1.80 ± 0.01mg/kg. It is clearly noticed that Zn concentration in all the dumpsites was much lower than maximum allowable limit of European Union standard (2002). The chief pollution sources of Zn in soils are metalliferous mining activities, agricultural use of sewage sludge and the use of agro-chemicals such as fertilizers and pesticides. Large concentrations of Zn in the soil have adverse effects on crops, livestock and human (Parth *et al.,* 2011).

As indicted in Table 2, the mean concentration of lead was (7.71 mg/kg) 15-30cm depth while for the 0-15cm depth the mean lead concentration was recorded as (1.77 mg/kg).The concentration of lead values in the dumpsites of Kano metropolis was far lower than 24.70-54.20 mg kg-1 reported by Akinbile, (2012) for land fill site at Akure, Nigeria. Parth *et al.*, (2011) also reported 42.90-1833.50 mg kg-1 lead in soil waste disposal sites in Hyderabad city, India. The Pb concentrations in all the dumpsites were within recommended threshold by European Union (2002) standard. However, (Awokunmi *et al.,* 2010) reported very high levels of lead in soils collected from various dumpsites located at Ikere and Ado Ekiti Metropolis, South Western Nigeria ranging between 3500-6860 mg/kg.

The concentration of cadmium was found in trace amount for the seven dumping sites with- the highest mean (0.025mg/kg) occurring at the depth of 15-30cm while lowest values was found at depth of (0-15cm) with concentration value of (0.012 mg/kg). This was different with the work reported by (Azeez *et al.*, 2013; Olarinoye *et al.*, 2009) whose cadmium concentration was found in the range of 0.003 to 0.006. Naturally occurring cadmium concentration ranges from 0.03 to 0.30µgg-1. Cadmium concentrations in the soils analyzed were found within the naturally occurring range. This is pollution especially when cadmium is known to be one of the most harmful pollutants, though cadmium was not detected in some of the soil samples analyzed.

As per results from Table 2, the level of Cr content in different sampling area was ranged from 0.274 at depth (0-15cm) to 0.31 mg/kg (15-30cm).Chromium concentration was higher than the results reported by (Amos, Bamidele, Onigbinde, 2013) for similar study at Yenagoa in Nigeria in which maximum concentration of chromium was found to be (0.005 mg/kg). Sources of Cr in the soils could be due to waste consisting of lead chromium batteries, coloured polythene bags, discarded plastic materials and empty paint containers (Jung *et al.,* 2006).

The result of Nickel concentration as showed in the table 2 revealed that the mean concentration of Ni in soils at depth of soil (0-15cm) was 0.49 mg/kg while lowest mean concentration (0.45 mg/kg) was found at a depth of (15-30cm) .Nickel concentrations in soils at both waste dumping sites were also lower compared to similar study at Kenya, Kadhodeki municipal solid waste dumping sites (17.44 mg/kg) (Murugi, 2009).

The Ni concentration in this study was comparatively higher than (0.222 mg/kg) reported by Onu *et al* (2021) for similar study in a farmland near market dumpsite in Zaria, Nigeria.

Contamination factor and pollution load index of the soils in the Study Area

The result of Contamination factor (Cf) in Table 3 indicated that all of the heavy metals in the surface and surface soils were in the class of very slightly contamination. The Cf values recorded for surface soils (0-15cm) ranged between 0.002-0.02 while for sub-surface soils the contamination factor (Cf) values ranged from (0.003-0.02). The result of contamination factor is in dis-agreement with the work of Shittu *et al.,* (2018) who reported higher contamination of heavy metals and pollution load index at Ilokun dumpsite, Ado Eki, Nigeria. Similarly, Elias *et al* (2011) reported low contamination for Cd, Zn and Cr at dumpsite in Lagos Mainland Area. However, the levels of contamination factor obtained in the present study were lower than those reported by Ogunmodede *et al.,* 2017 (0.47-11.78) in South-West Nigeria.

Table 3 shows the summary of pollution load index value in the five studied heavy metals (Zn, Pb, Cd, Cr and Ni) which indicates that there is minimal pollution load in the study sites (PLI less than 1).The Results of pollution load index obtained in the present study were lower with the work of Ikpe *et al* (2018) who reported PLI ranged between (1.83-8.26)in soils of three auto mechanic villages in Abuja. Also, the result of the pollution load index were also lower than value reported by Yahaya *et al.* (2021) in contaminated soils of three mining villages in Zamfara State, Nigeria.

Table 3 Contamination factor and Pollution load index of soils in the study area

Parameters	**Zn**	**Pb**	**Cd**	**Cr**	**Ni**	**PLI**
Mean (0-15)	0.30	1.71	0.012	0.27	0.49	
DPR (2002)	140	85	0.88	100	35	
Cf (0-15)	0.002	0.02	0.01	0.0027	0.01	$2x10^{11}$
Mean(15-30)	0.50	7.71	0.025	0.31	0.45	
Cf (15-30)	0.003	0.09	0.02	0.0031	0.01	$3x10^{10}$

Where Cf stand for contamination factor, PLI- Pollution load index, DPR- Department of petroleum Resources (2002) standard

Ecological risk Factor and potential ecological Risk of the soil in the Study Area

Table 4 shows the results of ecological risk factor and potential ecological risk index (PERI). The mean value of the ecological risk factor (Er) ranged from 0.0054 to 0.30 for surface soil (0-15) cm while sub-surface soil, the value of ecological risk factor ranged from 0.005 to 0.6 .It was found that ecological risk factors for Zn, Pb, Cd, Cr, and Ni were below 1.0, thus indicating low ecological risk.

Table 4 Ecological risk Factor and potential ecological Risk in the Study Area

Parameters	**Zn**	**Pb**	**Cd**	**Cr**	**Ni**	RI
Tf	1.0	5.0	30	2.0	5.0	
Er (0-15)	0.002	0.1	0.3	0.0054	0.07	0.41
Er(15-15)	0.002	0.045	0.6	0.0050	0.05	0.61

WhereTf stand for toxic Response factor, Er, ecological risk factor and **RI**, Potential ecological Risk (PERI)

The values of ecological risk factor (Er) obtained in the present study were similar with the work of Yahaya *et al* (2021) in contaminated soils of three mining villages in Zamfara State, Nigeria. Similarly, Jinal *et al* (2017) in Nashik District, India reported the higher value of potential ecological risk index of (146.5-307.0) which was far lower than values obtained in the present study.

CONCLUSION

The present paper aims to evaluate soil contamination with metals using single and integrated pollution indices in Soils around Municipal solid waste dumpsites of Kano Metropolis, Kano state, Nigeria. The concentration of the studied heavy metals (Zn,Pb, Cr, Ni and Cd) were far below the maximum tolerable levels set by European Union (EU, 2002) standard for heavy metal in soil.

The results of single pollution index shows that Contamination factor and ecological risk in the seven dumpsites were in the class of low contamination. The values of integrated pollution index in the studied dumpsites revealed that the potential ecological risk index (PERI) and pollution load index for five studied metals were found in the range of low contamination. It is therefore recommended, the regulation and legislation on environmental issues, including effective solid waste management strategies and enforcement of emission standards should be emphasized in order to reduce the illegal dumping of waste which lead accumulation of heavy metals on the urban dumping sites of developing countries.

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