JCHR (2019) 9(3), 173-190

Journal of Chemical Health Risks

www.jchr.org

ORIGINAL ARTICLE

Trace Metals Content of Soil around a Municipal Solid Waste Dumpsite in Gombe, Nigeria: Assessing the Ecological and Human Health Impact

Sulaiman Mohammad Bashir[1], Asegbeloyin Jonnie Niyi[*1], Ihedioha Janefrances Ngozi[1], Oyeka Ebube Evaristus[1], Oji Esther Onyinyechi[2]

[1]*Department of Pure and Industrial Chemistry, Faculty of Physical Sciences, University of Nigeria, Nsukka, Nigeria*

[2]*Department of Chemistry, Michael Okpara University of Agriculture, Umudike, Nigeria*

(Received: 13 March 2019 Accepted: 10 June 2019)

KEYWORDS

Municipal solid waste;
Dumpsite;
Trace metals;
Pollution indices;
Human health risk

ABSTRACT: The assessment of some trace metals in soils around a municipal solid waste dumpsite in Gombe, Nigeria was conducted. Pollution indices and health risk parameters were determined in order to evaluate the ecological and health risk to the local environment. The soil samples were collected in dry and rainy seasons and analysed for (Fe, Cd, Pb, Mn, Zn, Cu, Cr, and Ni) using atomic absorption spectrometry. The content of trace metals (mg kg^{-1}) at the dumpsite in dry season were: Pb (8.78), Zn (151.00), Ni (11.80), Cr (4.55), Cd (12.12) and Mn (92.05), while in rainy season, content of trace metals were Pb (8.80), Zn (148.00), Ni (11.63), Cr (4.20), Cd (10.03) and Mn (91.03). In both seasons, there was a significant increase ($p<0.05$) in levels of chromium, cadmium, zinc, nickel, lead, copper and iron in soil samples from the south (20 m) of the dumpsite and at the dumpsite compared to soil samples from the control site. Pollution indices studies showed that soil samples from south (20 m) of the dumpsite and at the dumpsite were highly polluted with cadmium, contributing 99% of the overall potential ecological risk. No potential health risk was detected, considering the fact that the hazard quotient and total hazard index of all the studied metals were less than one. However, children were found to be more vulnerable to heavy metal pollution than adults.

INTRODUCTION

Municipal solid wastes are discarded materials discharged as an outcome of human activity. Most commonly, they are semi solids, solids and liquids in containers discard out from industrial premises, markets or houses [1]. Solid waste management has been a major concern for most developing countries of the world. In Nigeria, for instance it is not strange to see heaps of trash in the main cities littering the vacant plots, streets, water bodies and dumped in drains, and this has resulted in spread of transmissible diseases in many areas. The situation appears to keep on unabated due to mostly the factors of population growth, improved life style, urbanization and insufficient funds to properly control solid waste. In Nigeria, management of waste generated from different sectors of the economy is the sole responsibility for agencies like the Federal Environmental Protection Agency (FEPA), Ministry of

*Corresponding author: niyi.asegbeloyin@unn.edu.ng (A. J. Niyi)
DOI: 10.22034/jchr.2019.668183

Environment, Local Authorities and Environmental Sanitation Authorities. Gombe State Environmental Protection Agency (GOSEPA) is not an exception. The report that refuse dumps have caused traffic delays in some strategic parts of some urban center is an example of poor management of refuse dumps in most Nigerian towns and cities [2]. Most of these agencies do not possess relevant managerial ability, structure and funds to meet up with the challenges of waste management. The inability of these agencies to function properly has led to the proliferation of open dumpsites across various city centers.

Improper management of solid waste might result in serious ecological, environmental and health problems. Contamination of groundwater and nearby soil is one major problem related to open dumpsites. This is as result of leachate production which could permeate the underground aquifer as well as migrate to neighboring farmlands. This could lead to the deterioration of soil by some chemical toxicant like trace metals. Soils are generally regarded as the carrier of most toxic trace metals release into the environment [3]. Consequently, continual disposal of municipal solid waste on soil may increase its trace metal burden. In recent times, environmental problem due to soil contamination by trace metals has received great global attention [4]. Some trace metals are of great ecological concern due to their bioaccumulation tendencies, non-biodegradable nature and toxicity [5]. Lead exposure has been associated with high blood pressure and hypertension [6], cadmium toxicity has been implicated in cases of prostate cancer and cancer in liver, kidney and stomach [7] while exposure to nickel can lead to reduced lung function, cancer of the lung, asthma and respiratory tract irritation [8]. The occurrence of these trace metals in municipal waste dumpsites in various parts of Nigeria has been reported, this includes relatively high content of lead, cadmium, mercury and arsenic in soil from an open solid waste dumpsite in Enugu, Nigeria. Also levels of chromium, copper, iron and lead found in soils near a dumpsite in Lagos, Nigeria were reported to be above regulatory bodies limits, and high cadmium concentration were recorded in soil near an open dumpsite in Uyo, Nigeria [9-11]. It has been reported that cadmium contributed 98–99 % of the overall potential ecological risk related with dumpsite in Uyo, Nigeria, but with no feasible health risk [11]. Assessment of ecological risk of trace metals in polluted soil has been gaining more attention in recent years [12-13]. These risk assessment methods can serve as means for analyzing, processing, and conveying relevant information to help maintain a healthy environment. In the present study, the levels of some metals in soils within the surrounding area of a municipal solid waste dumpsite are determined; the results are used to provide information on the health and ecological risk associated with the dumpsite.

MATERIALS AND METHODS

Study Area

The study area was Gombe metropolis,Gombe state capital, situated in the North-Eastern Nigeria.It is located between latitude 10°17′05.88"N and 11°10′36.78"E with an area coverage of about 52 km^2 and about 399,531 estimated population based on 3.2% growth rate [14]. The studyarea has Sudan savanna climate, characterized by a tropical climate with two distinct seasons; a rainy season (May-October) and a dry/harmattan season (November-April); with an average annual rainfall of 902 mm and temperature range from 18 ^oC to 39 ^oC [15]. Therelative humidity range from 70 to 80 % in August and decrease to 15 to 20% in December. Geologically, Gombe is part of the central highland with flat landscape [16]. The open dumpsite is located in the Herwagana Quarters very close a primary school (Figure 1).

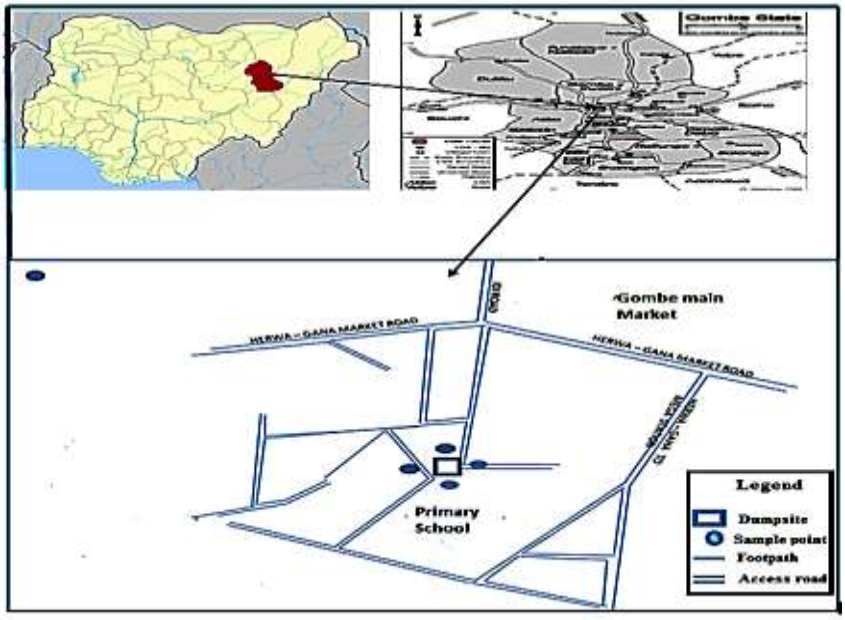

Figure 1. Map of the Study area.

Soil sample collection and processing

Soil samples were collected from six different locations: at the dumpsite, 20 m south, north and east and west of the dumpsite; and control site, a virgin soil 500 m away from the dumpsite. Stones and extraneous materials were removed from the sampling sites; samples were collected from top soil 5-15 cm under the surface to avoid collection of decayed waste materials. Five subsamples were randomly collected at each sampling location to make a composite sample. Ten samples were collected in both rainy and dry season at each sampling location. A total of sixty different composite samples were collected for the study. 500g of each soil sample was placed in polyethylene bag, and taken to the laboratory, where they were stored under room temperature until analysis.

Determination of soil physicochemical properties

The parameters determined were pH, electrical conductivity; cation exchange capacity, soil moisture, organic matter, total nitrogen, available potassium, available phosphorus, available sulphate and particle size distribution. pH was determined using WTW pH Electrode, conductivity was determined using a CO150 conductivity meter, soil organic matter (OM) was determined by the potassium dichromate titrimetric method, soil total nitrogen (TN) was determined by the semi-micro Kjeldahl method, available phosphorus (P_A) was determined by Bray's extractant spectrophotometry method, available potassium (K_A) was determined by the ammonium acetate spectrophotometry method, available sulphur (S_A) was determined by spectrophotometry method, cation exchange capacity was determined by the neutral ammonium acetate method while the particle size was determined by using hydrometer test [17].

Sample preparation and digestion of soil

The soil samples were air dried and sieved through 2 mm mesh standard sieve.1.00 g of each prepared soil sample was put into 150 ml erlenmeyer flask, concentrated mixture of HNO_3:$HClO_4$:HF, (3:1:3) was added. The mixture was placed on a hot plate for three hours at 80 ^oC. The digest was filtered into 100 ml standard flask and made to mark with distilled water [18]. Cu, Cr, Fe, Ni, Cu, Mn, Cd and

Zn, were all determined using an atomic absorption spectrophotometer AAS (Unicam 969).

Quality assurance protocol

Precision and accuracy of the analytical procedure was investigated by conducting recovery experiments. The quality assurance protocol was obtained by determining metal concentrations in triplicate samples of un-spiked and spiked soil samples. Spiking was performed by adding 1 ml of different concentrations of the metal standard solution to 1 g of soil sample, prior to the digestion process. Mean of the metals recoveries were Fe:90 ± 6.60%; Pb:94±4.0%; Zn:92±6.0%; Ni:89±5.5%; Cr:95±3.0%; Cd:97±4.0%; Cu:86±5.6%; 91±4.3%.

Data analysis

The data obtained from the study were analysed with SPSS software version 20 for windows. The independent t-test was used to compare the mean values obtained during the rainy season with that of dry season, and also to compare mean values from soil at the dumpsite with soil outside the dumpsite at $p < 0.05$. Pearson Correlation of different metals in soil samples was calculated. Cluster analysis of the eight heavy metals was performed to spot the connection among the heavy metals and to group them according to their probable sources. A dendrogram was constructed to show the cohesion of the observed clusters.

Pollution indices

Geo-accumulation Index

Geo-accumulation Index is defined as enrichment of metal concentration above baseline concentrations, and it was calculated using literature method [19]. This method was used to assess the metal pollution in terms of seven (0 to 6) enrichment classes ranging from reference concentration to very heavily polluted, as follows:

$$I_{geo} = \mathrm{Log}_2 \left[\frac{C_n}{1.5\ Bn}\right] \qquad \text{Eq.1}$$

Where C_n is the concentration of the examined trace metal in the soil sample, 1.5 is introduced to minimize background variations and B_n is the reference value of the metal n or geochemical background concentration. The reported world average elemental concentration in mg kg^{-1} (Fe = 47200, Cr = 90, Cd = 0.30, Cu = 45, Ni = 68, Mn = 850, Pd = 20 and Zn = 95) [20]. An approach which was reported in the literature [21] was used, seven classes contamination are used to define the degree of metal pollutants in soils [20]. The classes include (unpolluted) $I_{geo} < 0$, (unpolluted to moderately polluted) $0 \leq I_{geo} < 1$, (moderately polluted) $1 \leq I_{geo} < 2$, (moderately to strongly polluted) $2 \leq I_{geo} < 3$, (strongly polluted) $3 \leq I_{geo} < 4$, (strongly to very strongly polluted) $4 \leq I_{geo} < 5$ and (very strongly polluted) $I_{geo} > 5$.

Enrichment factor

The enrichment factor shows the level of accumulation of the metal to the natural background level. The enrichment factors of metals in soil were calculated based on the equation:

$$EF = \frac{\left(\frac{M}{R}\right)sample}{\left(\frac{M}{R}\right)shale} \qquad \text{Eq.2}$$

Where, EF enrichment factor, M is the metal, R is the reference metal, (M/R) sample is the metal ratio found in sample, and (M/R) shale is the metalreference ratio. It has been reported that Fe is essentiallylactogenic [22], and therefore not expected to be considerably enriched from anthropogenic source in estuarine soil [23]. Iron was used for normalization study to determine the heavy metal pollution. The classification of enrichment factor (EF) reported elsewhere [13] was adopted in this study; EF < 2 (indicates no enrichment), EF = 2 to 3 (minor enrichment), EF = 3 to 5 (moderate enrichment), EF = 5 to 10 (moderately severe enrichment), EF = 10 to 25 (severe enrichment), EF = 25 to 50 (very severe enrichment) and EF > 50 (extremely severe enrichment).

Degree of Contamination (C_d)

To express the contamination of toxic metals in this study, equations3 and 4 were used to define contamination factor (C_f) and degree of contamination (C_d) respectively;

$$C_f = \frac{C_n}{C_o} \quad \text{Eq.3}$$

$$C_d = \sum C_f \quad \text{Eq.4}$$

Where C_n is the metal content in the soil and C_o is the geochemical background concentration or the background value of heavy metals in the uncontaminated soil or reference value of the metal [24]. The following terminology was used to express the contamination factor: low contamination $C_f < 1$; moderate contamination $1 < C_f < 3$; considerable contamination $3 < C_f < 6$; very high contamination factor $C_f > 6$. Degree of contamination (C_d) is the sum of all contamination factors and is graded as follows: low degree of contamination $C_d < 8$; moderate degree of contamination $8 < C_d < 16$; considerable degree of contamination $16 < C_d < 32$; very high degree of contamination $C_d > 32$.

Pollution load index (PLI)

Pollution load index (PLI) was calculated based on literature procedure [24]

$$PLI = (Cf_1 \times Cf_2 \times Cf_3 \times Cf_4 \ldots Cf_n)^{1/n} \quad \text{Eq.5}$$

Where *Cf*is the contamination factor and n is the number of metals studied. The PLI gives an estimate of the metal concentration status. The values of PLI < 1 denotes perfection; PLI = 1 means that only baseline levels of pollutant are present and PLI > 1 indicates deterioration of site quality [25,26].

Ecological Risk Assessment

United States Environmental Protection Agency (USEPA) in 1998 defined ecological risk assessment as a process that determines the likelihood that certain adverse ecological effects may occur. The assessment of ecological risks of heavy metals in the studied soil samples was done using the parameters; Ecological Risk Assessment E^i_r and Potential Ecological Risk Index (R_i) according to literature method [27]. The ecological risk index (R_i) was used to assess the degree of heavy metal pollution in soil, in accordance with the toxicity of metals and the response of the environment. The formulas for determining R_i and $E^i_r$are given as:

$$R_i = \sum E^i_r \quad \text{Eq. 6}$$

$$E^i_r = T_i \frac{C_n}{C_o} \quad \text{Eq. 7}$$

Where $R_i$isthe sum of potential ecological risk factor for trace metals in soil , *Ti* is the toxic-response factor of a certain metal (e.g., Cd = 30, Cu = 5, As = 10, Pb = 5, Ni =5 Zn = 1 and Cr = 2). $E^i_r$is the monomial potential ecological risk factor, $C_n$is the metal content in the soil and C_o is a background value or reference value of metals in soil.

To quantitatively describe the potential ecological risk (E^i_r) of contaminant in soil of the study area, the potential ecological risk factor was calculated using equation 7. The following terminology was used to described the potential ecological risk factor:$E_i < 40$ (low potential ecological risk), $40 < E^i_r < 80$ (moderate potential ecological risk), $80 < E^i_r < 160$, (considerable potential risk ecological risk), $160 < E^i_r < 320$ (high potential ecological risk),and $E^i_r > 320$ (very high potential ecological risk).

Health Risk Assessment

Human health risk assessment is the method of estimating the probability of adverse health effects of toxic elements in humans. Risk assessment of heavy metals are usually estimated oral ingestion (food, water etc), dermal contact (soil) and inhalation (dust), but assessment carried out in the study is based on accidental oral ingestion of soil medium [28,29]. The model for estimatingnon-carcinogenic risk is as follows:

$$ADD_{ing} = \frac{C \times IR \times EF \times ED}{BW \times AT} \times 10^{-6} \quad \text{Eq.8}$$

Where ADD_{ing}isaverage daily dose of ingestion, C = concentration of the contaminant in the medium (mg/kg); IR = ingestion rate is 200 mg $day^{-1}$for children and 100 mg day^{-1} for adults [30] EF = exposure frequency is 250 $daysyear^{-1}$ [31]; ED = exposure period (6 years for children and 25 years for adult) (USEPA, 2001); AT = average time for non-carcinogensis ED×365 days and BW = body weight; 15 kg for children and 70 kg for adults [29]. The non-carcinogenic hazard or systemic toxicity for each metal is expressed as the hazard quotient:

Non-cancer Hazard Quotient (HQ) $= \frac{ADD_{ing}}{RfD}$ Eq.9

Rfd is reference dose for the metal [32].

The cumulative non-carcinogenic hazard is expressed as the total hazard index (THI) and it is the summation of all the individual hazard quotients;

Total Hazard Index (THI) = $\sum^{n}_{i-1}$HQ Eq.10

If values of HQ and HI are above 1, it calls for a greater level of concern [28]. The possibility of experiencing long-term health hazard effects increases with the increasing THI value [33], THI = 1.1-10 refers to moderate hazard while THI >10 refers to high hazard [34].

RESULTS AND DISCUSSION

Physico-chemical properties

Table 1 presents the physico-chemical properties of the soil at the dumpsite and around the dumpsite. The pH values recorded in all soil samples during the wet season range from 8.06 to 8.63 whereas during the dry, the values range from to 7.45 to 8.0.The electrical conductivity of soil samples at the dumpsite was higher than values recorded for the other sites while lower values was observed at 20m south of the dumpsitein both seasons compared to the other sites. The soil samples recorded organic carbon percentage which range between 0.84 to 1.20 % during thewet season and 0.87 to 1.22 % during the dry season. The dumpsite recorded a higher organic carbon compared to other sites. This could be attributed to presence of decayed organic waste residues in the dumpsite. The percentage of nitrogen in all soil samples range from 0.063 to 0.147 % during the wet season whereas during the dryseason, the values range from 0.063 to 0.163 %, these values are lower than those reported for refuse dump soils and plants in Ghana [35], which range from 0.22 to 0.42 %. The concentration of available phosphorus in the dumpsite during wet season range from 12.86 to 55.62 mg kg^{-1} whereas during dry season the values range from 14.76 to 61.68 mg kg^{-1}. These values were relatively higher than those reported elsewhere [36], with values range of 11.00 to 46.00 ppm. The available potassiumrecorded for the studied soils, range from 10.09 to 23.64 mg kg^{-1} during wet season and 13.70 to 28.28mg kg^{-1} during dry season, the concentrations of available potassium in the dumpsite were higherthan (2.34 to 8.31 mg kg^{-1}) reported for the soil dumpsite in Bonoua, Ivory Coast [37], but lower than (15169 to 22680 mg kg^{-1}) reported for the soil in some dumpsites located in IkotEkpene, Nigeria [36]. The available sulphur recorded for the dumpsite soil in the present study area during wet season range from 8.11 to 23.19 mg kg^{-1} whereas during dry season the values range from 8.22 to 28.36 mg kg^{-1}, these values were lower than 3.72 to 102.64 mg kg^{-1} reported for dumpsites in Zaria Metropolis, Nigeria [38].

Table 1. Physicochemical properties of soils sampled along wastes and non-waste dumpsites in Gombe

Location	Dry season (n = 30)									
	pH	**EC(µS/cm)**	**CEC(cmol(+)/kg)**	**Sandy %**	**Silt %**	**Clay %**	**% Moisture**	**% Org C**	**$N_{T\ (\%)}$**	**$P_{ava\ (mg/kg)}$**
SSC	7.60 ± 0.14	240±29.15	7.25 ± 0.575	68.40±1.57	19.28±1.02	16.32±3.41	0.235±0.08	0.65 ± 0.028	0.63 ± 0.014	19.30 ± 1.71
SSD	8.00 ± 0.28	1360±62.45	18.63 ± 1.25	64.40±1.298	20.84±1.66	14.76±2.71	0.376±0.06	1.22±0.014	0.163±0.025	61.68 ± 2.36
SSE	7.60 ± 0.14	780±40.00	9.86 ± 0.823	72.40±2.50	11.38±1.47	16.32±3.41	0.25±0.107	0.94 ± 0.028	0.084±0.010	24.59 ± 1.42
SSW	7.45 ± 0.07	630±35.36	12.75 ± 1.09	58.40±1.59	19.28±1.10	22.32±2.05	0.294±0.12	0.89 ± 0.014	0.084±0.018	27.6 2± 1.10
SSN	7.55 ± 0.07	280±26.08	12.75 ± 1.09	62.40±2.50	21.84±1.47	20.32±3.21	0.235±0.75	0.87 ± 0.140	0.084±0.056	15.89 ± 1.77
SSS	7.50 ± 0.14	240±50.00	8.09 ± 1.300	56.40±2.45	21.28±2.26	22.32±4.04	0.338±0.07	0.92 ± 0.042	0.063±0.014	14.76 ± 1.60
	Rainy season (n=30)									
SSC	7.73 ±0.06	220±33.91	6.31 ± 0.520	70.40±1.25	17.28±0.86	12.32±1.17	0.338±0.07	0.65 ± 0.280	0.063±0.018	16.65±1.853
SSD	8.63 ±0.05	1640±71.06	16.17±0.828	66.40±1.77	15.28±1.08	18.31±1.43	0.842±0.13	1.20±0.0280	0.147±0.023	55.62 ±0.092
SSE	8.25 ±0.08	670±48.48	8.14 ± 0.890	74.40±1.465	13.28±0.842	12.76±2.01	0.482±0.72	0.92± 0.42	0.084±0.056	20.05±0.871
SSW	8.53 ±0.09	560±62.45	9.46 ± 0.792	64.40±1.77	15.28±1.08	15.67±3.41	0.475±0.10	0.87 ± 0.014	0.63±0.017	23.46±1.611
SSN	8.06 ±0.04	320±43.01	9.45 ± 0.792	64.40±2.163	17.28±1.57	18.32±1.21	0.338±0.11	0.84 ± 0.015	0.084±0.018	14.38±1.454
SSS	8.46 ±0.05	280±35.36	6.92 ± 0.830	60.40±2.50	19.28±0.86	20.32±3.21	0.4960.14	0.89 ± 0.014	0.63±0.018	12.86±1.420

SSC=Soil sample from control site, SSD=Soil sample from dumpsite,SSE=Soil sample from east of dumpsite ,SSW Soil sample from west of dumpsite =,
SSN= Soil sample from north of dumpsite,SSS= Soil sample from south of dumpsite

Trace metals content in the soil

Table 2 shows the mean concentrations of trace metals in soil around the dumpsite. The highest concentrations of iron (2440.00mg kg^{-1}), cadmium (12.22 mg kg^{-1}), manganese (92.05mg kg^{-1}), lead (8.80 mg kg^{-1}), chromium (4.55 mg kg^{-1}), nickel (11.85 mg kg^{-1}), copper (2.15 mg kg^{-1}) and zinc (151.00 mg kg^{-1}) were recorded in the soil samples from the dumpsite in both seasons. Copper (0.23 mg kg^{-1}) recorded lowest concentration from soil sample east of the dumpsite, while soil sample north of the dumpsite recorded low concentration of cadmium (4.55 mg kg^{-1}) during the wet season. The high iron concentrations in the soil samples could not be from anthropogenic sources alone, lithogenic origin is amajor source of iron in soil [36]. Moreover, reports have shown that iron is one of the abundant metals in Nigeria soils[39].There is an increase in zinc content of soil samples from west of the dumpsite, which could be ascribed to leachate from the dumpsite. Low concentration of iron was recorded for soil sample 20 m west of the dumpsite while soil samples from 20m north of the dumpsite recorded low zinc content. The increase in heavy metal levels of soil samples from 20 m south of the dumpsite as well as the dumpsite gave an indication of the proportion of waste dumped in study area. The general trend for the trace metals in the soil samples is Fe > Zn >Mn>Pb> Ni > Cd > Cr > Cu. The mean metal concentrations (Cr, Fe, Cu, Mn, Zn, Ni, and Pb) in all the soil samples were lower than the target limit (Cu = 36. Mn = 476, Fe = 5000, Pb = 85, Zn = 140, Ni = 35 and Cr = 100 mg kg^{-1}) [40]. However, the Cd concentration in all the soil samples from control site, 20 m south, north, west and east, and the dumpsite were above 0.80 mg kg^{-1} limit set by a regulatory body [40]. Similar observation of metal levels above regulatory body's stipulations [40] was reported for soils around a dumpsite in Uyo, Nigeria [11] and dumpsite soil in Bonoua, Ivory Coast [37]. Cadmium is frequently discharged from anthropogenic sources. Cadmium is used as an anticorrosion coating in electroplating, stabilizer in plastics, it is also a component of nickel-cadmium batteries, it is used as alloying metal in solders, as component of phosphate fertilizers, and as pigments; all these constitute potential sources of cadmium at dumpsites, where there are accumulation of discarded wastes. The Cd levels in the present study was higher than 0.73mg kg^{-1} reported for dumpsite soil in Ghana [41], 0.84 mg kg^{-1}obtained for dumpsite soil from Ibadan, Nigeria [42] and 9.05 mg kg^{-1} observed in dumpsite soil from Uyo, Nigeria [11]. However, the Pblevels were lower than 9.90 mg kg^{-1}, 41.82 mg $kg^{-1}$and 149.67mg kg^{-1}reported for dumpsite soils in Uyo[11], Ghana [41]and Nigeria [43] respectively. Most of the other metals such as Zn,Mn, Cr, and Fe levels in this study were higher than values reported in related studies [11, 41, 42]. It was found that in the rainy season, the metal content declined. This might be ascribed to heavy rainfall, dilution and run-off during the rainy season.There was a significant increase ($p<0.05$) in levels (in both seasons) of lead, iron, cadmium, zinc, nickel, copper and chromium in soils from south of the dumpsite and in the dumpsite as compared to the soil from the control site. However, in both seasons, soil samples from 20 m north, and east of the dumpsite as well as the dumpsite recorded significantincrease in manganese ($p<0.05$) content compared to samples from the control site.

Table 2. Trace metal concentrations (mg kg^{-1}) of soils sampled along wastes and non-waste dumpsites in Gombe

Location	Dry season (n = 30)							
	Cd	**Cu**	**Mn**	**Fe**	**Pb**	**Zn**	**Ni**	**Cr**
SSC	1.09±0.03	0.28±0.08	44.17±0.50	1797.56±2.00	3.78±0.05	50.90±3.00	2.19±0.03	1.06±0.02
SSD	12.22±0.19	2.15±0.61	92.05±1.92	2440.00±3.0	8.78±0.5	151.0±1.0	11.85±1.00	4.55±0.05
SSE	1.70±0.10	0.83±0.25	46.60±0.50	1899.50±4.0	6.90±0.2	72.25±1.05	2.50±0.30	1.95±0.12
SSW	1.92±0.10	0.68±0.38	54.50±0.50	1814.00±4.0	5.6±0.33	147±2.0	2.85±0.05	1.7± 0.02
SSN	1.75±0.01	0.25±0.20	61.75±0.46	1989.50±3.0	4.10±0.1	66.55±0.45	3.75±0.05	1.65±0.03
SSS	6.60±010	1.34±0.60	81.20±0.80	1865.00±4.0	7.83±0.4	61.57±0.27	9.55±0.65	3.25±0.14
	Rainy season (n=30)							
SSC	1.09±0.03	0.26±0.09	44.27±0.50	1797.5±2.000	3.78±0.05	50.90±3.00	2.190±0.03	1.06±0.02
SSD	10.03±0.15	1.34±0.60	91.03±1.0	1998.80±0.53	8.80±0.2	148.0±0.5	11.63±0.59	4.20±0.25
SSE	1.61±0.05	0.23±0.09	44.27±0.5	1865.00±\2.0	6.35±0.25	70.05±1.15	2.00±0.10	1.74±0.15
SSW	1.80±0.09	0.52±0.41	49.45±0.65	1797.60±2.0	5.30±0.2	137.0±3.0	2.50±0.10	1.72±0.14
SSN	1.60±0.05	0.25±0.09	55.50±0.5	1946.00±3.0	4.00±0.1	60.33±0.5	3.10±0.11	1.60±0.10
SSS	6.73±0.10	0.82±0.28	62.80±0.5	1845.00±3.0	6.90±0.5	50.90±2.0	7.50±0.40	2.90±0.10
DPR target values	**0.8**	**36**	**476**	**5000**	**85**	**140**	**35**	**100**

SSC=Soil sample from control site, SSD=Soil sample from dumpsite, SSE=Soil sample from east of dumpsite, SSW Soil sample from west of dumpsite =,SSN= Soil sample from north of dumpsite, SSS= Soil sample from south of dumpsite

Correlation and Cluster analysis

Pearson correlation analysis was performed for metal contents in all the sites at levels of significance ($p < 0.05$ and $p<0.01$) and the results are presented in Table 3. The results indicated that most metal pairs have strong and positive correlations ($r>0.6$) except Zn pairs that had $r \leq 0.4$. Some metal pairs showed strong significant ($p< 0.05$ and $p<0.01$) indicating their simultaneous release from the dumpsite. Cluster analysis was used to recognize the link among the analysed metals and group their likely sources. The distance cluster portrays the extent of association between the metals. A low distance cluster value indicates a more significant relationship. The results of the cluster analysis in both seasons were illustrated in a dendrogram that grouped the eight metals into two distinct clusters (Figure 2). The first cluster in both dry and rainy seasons includes Cu, Cr, Cd, Ni, Pb, Mn and Zn. These metals draw attention to the anthropogenic sources which are associated with the dumpsite. The second cluster varied in the two seasons. In dry season, it was with Ni and Fe while in rainy season, it was Cu and Fe. However, the degree of difference in second clusters was very great. The non-association of Fe indicates that iron is mainly lithogenic and could not have been discharged from the dumpsite.

Table 3. Pearson correlation matrix for the trace metals in the soils in both seasons

Metals	Cd	Cu	Mn	Fe	Pb	Zn	Ni	Cr
				Dry season				
Cd	1							
Cu	.956(*)	1						
Mn	.935(*)	.817	1					
Fe	.833	.738	.707	1				
Pb	.820	.942(*)	.657	.522	1			
Zn	.433	.459	.259	.481	.277	1		
Ni	.962(**)	.893(*)	.982(**)	.699	.782	.237	1	
Cr	.992(**)	.972(**)	.919(*)	.793	.874	.360	.965(**)	1
				Rainy season				
Cd	1							
Cu	.967(**)	1						
Mn	.937(*)	.933(*)	1					
Fe	.530	.451	.735	1				
Pb	.880(*)	.858	.754	.357	1			
Zn	.359	.566	.487	.173	.434	1		
Ni	.994(**)	.963(**)	.967(**)	.603	.836	.371	1	
Cr	.992(**)	.972(**)	.952(*)	.573	.906(*)	.437	.988(**)	1

* Correlation is significant at the 0.05 level (2-tailed).
** Correlation is significant at the 0.01 level (2-tailed).

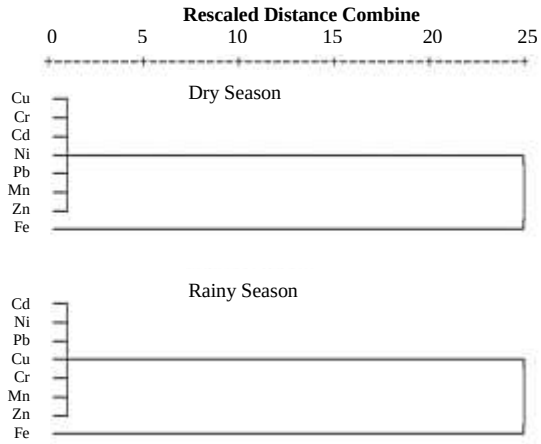

Figure 2. Dendrograms produced by hierarchical clustering

Pollution indices

The results of the geo-accumulation index of the soil samples from the various sites in both seasons are presented in Figure 3. In both seasons, the dumpsite soil had Cd I_{geo} of 4.7 and 4.5which implies that the site range from strongly to very strongly polluted while the other sites had I_{geo} ranging from moderately to strongly polluted with cadmium. The other metals (Cu, Mn, Pb, Zn, Ni, Cr and Fe) had I_{geo} values ranged from unpolluted to moderately polluted in both seasons. The I_{geo} values in this study were similar to values reported in a related study [11], butlower than values of Ni and Pb reported for dumpsite soils in Khamees-Mushait, Saudi Arabia [44]. The results of enrichment factor in both seasons (Figure 4) show that Cu and Cr (EF < 2) recorded no enrichment, Mn and Ni recorded a range of no to minor (EF = 2 to 3), while Pb recorded moderate enrichment (EF = 5 to 10) in all the sites. However, severe enrichment (EF = 10-25) was recorded for Zn, while extremely severe enrichment was recorded for Cd (EF > 50) in all the sites. Extremely high enrichment for Cd and Zn was reported in similar study [11], while minimal enrichment has been reported for Cd in soil from a waste dumpsite in Ghana [41]. Results of enrichment factors may vary for different studies depending on the reference values used in the assessment. Some studies use the background levels, average crust levels, pre industrial reference levels or the average shale levels of the various metals. The present study used the average shale level as the heavy metal reference values in soil. The results of the contamination factor in both seasons (Figure 5) indicated low contamination for all the metals in the different sites except Cd. Very high contamination (C_f> 6) was recorded for Cd at the dumpsite and 20m south of the dumpsite, while the other sites recorded moderate contamination (1 <C_f< 3) in both seasons. Considerable degree of contamination (16 < C_d< 32) was recorded for Cd at the dumpsite, moderate contamination (8 < C_d< 16) at south of the dump (20 m) while low degree of contamination was recorded in all the other sites. The pollution load index values (Figure 5) of each of the metals were less than 1 at the different sites of the dumpsite. This is an indication that the studied sites have not been severely contaminated, and consequently there may beno need for immediate intervention to ameliorate hazardous pollution. Similar contamination factor ranging from moderate to severe pollution and PLI less than 1 for Cd has been reported elsewhere [11]. The results of the ecological risk assessment are summarized in Table 4for rainy and dry seasons. It was observed that the value of E_r^i for lead, copper, zinc, nickel and chromium were below 40 in both seasons indicating low potential ecological risk. However, moderate ecological risk (E_r^i = 63 to72) was recorded for Cd in soil samples 20m north, east and west of the dumpsite while the soil 20m south of dump with E_r^i= 214 to 248 fell under high potential ecological risk. The

dumpsite soil had E_r^i= 375 to 458 which depicts very high potential ecological risk. The risk grade for the various sites was evaluated and it was found that Cd contributed to 99% of the overall potential ecological risk in the studied sites. This is an indication that cadmium may pose a potential risk to the surrounding biota. Most of the municipal dumpsites in Nigeria have agricultural farms close to them. Most of these metals especially Cd could be leached into these farmlands and contaminate agricultural produce. Most pollution studies at dumpsite in some Nigerian cities have shown that Cd may pose a high ecological risk, the values of potential ecological risk for the studied waste dumpsites range from 91-99% [11, 42-46]. This might be attributed to appreciable cadmium levels in the Nigerian environment. Several studies have reported high cadmium in various matrixes. For instance high levels of Cd have been observed in muscles and offals of cow reared in Nigeria [47], some goat meats in Nigeria have been reported to be impaired with high levels of Cd [48], likewise, Cd levels in all rice samples from seven states in Nigeria have been reported to be above the Codex standard [49]. Nigeria is a densely populated country with little or no waste management policies. These toxic metals, if not properly managed could be discharge into the environment thereby affecting the food chain.

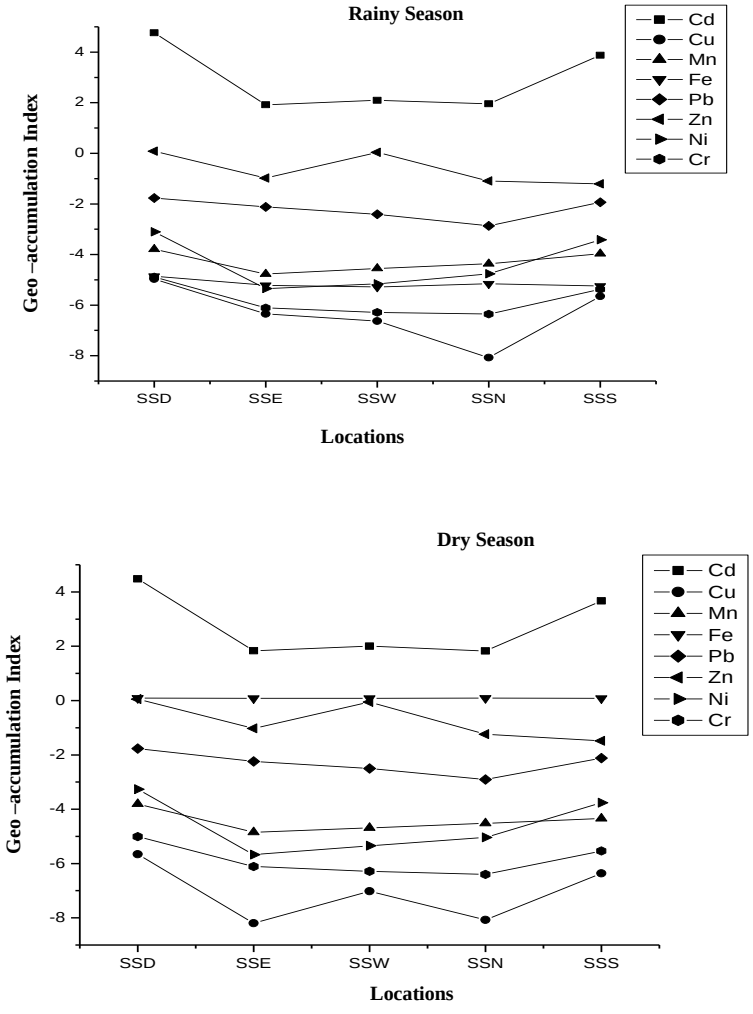

Figure 3. Geo-accumulation index (I_{geo}) of the metals in soil for rainy and dry seasons

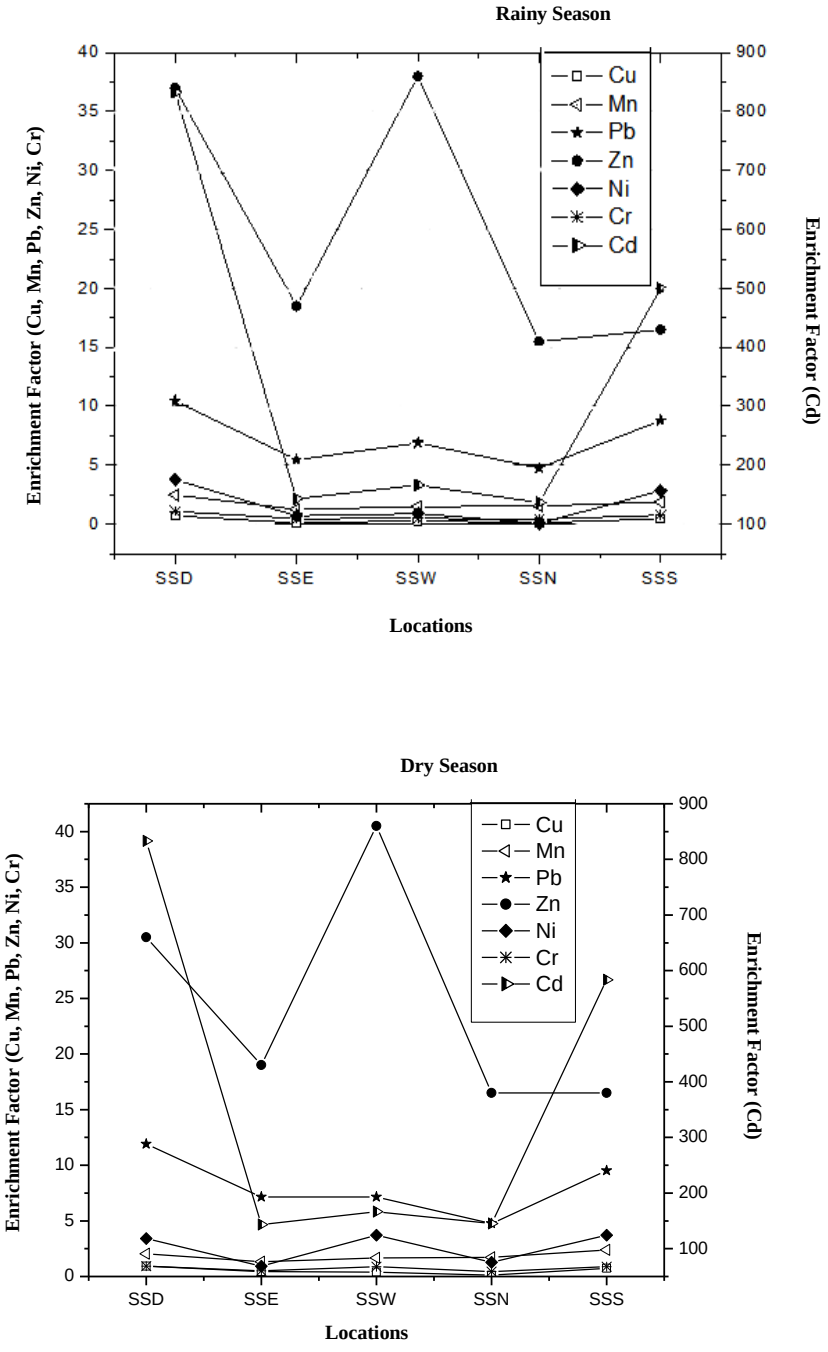

Figure 4. Enrichment factor (EF) of the metals in soil from rainy and dry seasons

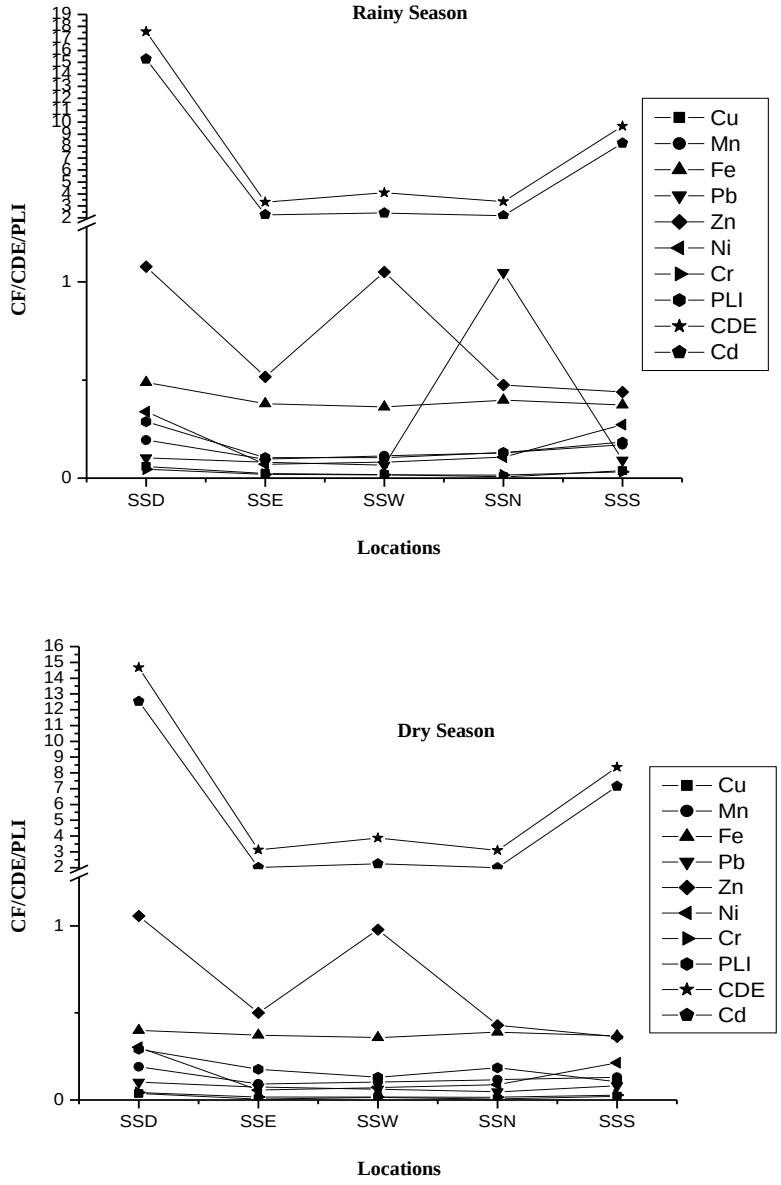

Figure 5. Contamination factor/Degree of contamination/Pollution load index of the metals in soils for rainy and dry seasons

Table 4. Potential ecological risk factor (E^{i}_{r}) and ecological risk index (R_i) values of soil sampled along wastes and non-waste dumpsites in Gombe

Location	Dry season							
	E_r						R_i	Risk grade
	Cd	Cu	Pb	Zn	Cr	Ni		
SSD	458.22	0.295	0.515	1.078	1.69	0.090	461.8	Considerable
SSE	63.75	0.115	0.405	0.516	0.355	0.038	65.17	Low
SSW	72.00	0.180	0.330	1.050	0.405	0.034	73.99	Low
SSN	65.61	0.030	0.240	0.475	0.535	0.032	66.92	Low
SSS	247.5	0.185	0.460	0.439	1.360	0.064	250.0	Moderate
Potential ecological risk	Moderate to very high	Low	Low	Low	Low	Low		

Table 4. Continued.

				Rainy season				
SSD	375.9	0.185	0.515	1.057	1.515	0.084	379.25	Considerable
SSE	60.3	0.031	0.074	0.500	0.285	0.034	61.22	Low
SSW	67.5	0.070	0.310	0.978	0.335	0.034	69.24	Low
SSN	60.0	0.034	0.235	0.430	0.440	0.032	61.17	Low
SSS	214.8	0.110	0.405	0.363	1.070	0.058	216.80	Moderate
Potential ecological risk	Moderate to very high	Low	Low	Low	Low	Low		

SSC=Soil sample from control site, SSD=Soil sample from dumpsite, SSE=Soil sample from east of dumpsite ,SSW Soil sample from west of dumpsite =,SSN= Soil sample from north of dumpsite, SSS= Soil sample from south of dumpsite

Health risk assessment

Table 5 presents the results of ADD, HQ and THI of heavy metals ingestion for both child and adult. It was found that child health risk for each metal in the dumpsite and other sites were consistently higher than adult health risk. Children may take in more heavy metals from soils than adults during their outside play activities, and this could result to children being more exposed to soil toxic metals [50]. The total hazard indexes (THI) of all the metals were less than 1, this indicate that there was little or no likely adverse health risk. Although, ecological risk results have shown that the study area is polluted with cadmium, THI showed no adverse health effect. This is attributed to the fact that THI was carried out only on oral ingestion of soil. Other exposure routes like inhalation, dermal contact and even ingestion of food crops and water around the study area were not carried out in this study. THI reported in this study is similar to values observed in related study [11].

Table 5. Health risk assessment of the trace metals in soil from a dumpsite in Gombe, Nigeria

Metals	Mean metal conc(mg/kg)	Age group	ADD	RfD	HQ
Cd	4.60±4.02	Child	4.20E-05	1.00E-03	4.2E-02
		Adult	4.50E-06		4.5E-03
Cu	0.84±0.62	Child	7.68E-06	4.00E-02	1.92E-04
		Adult	8.24E-07		2.06E-05
Mn	63.92±17.91	Child	2.92E-04	1.40E-01	2.08E-03
		Adult	6.25E-05		4.47E-04
Fe	1946.04±186.68	Child	6.66E-03	7.00E-01	9.52E-03
		Adult	1.89E-03		2.70E-03
Pb	6.46±1.72	Child	5.88E-05	4.00E-03	1.47E-02
		Adult	6.32E-06		1.58E-03
Zn	96.47±42.95	Child	8.82E-04	3.00E-01	2.94E-03
		Adult	9.44E-05		3.15E-04
Ni	5.72±3.99	Child	5.22E-05	2.00E-02	2.61E-03
		Adult	5.58E-06		2.74E-04
Cr	2.53±1.13	Child	1.03E-05	1.5E+00	1.54E-05
		Adult	2.48E-06		1.65E-06
		Child			**7.41E-02**
	THI	**Adult**			**9.84E-03**

CONCLUSIONS

Assessment of pollution by some trace metals is soils within a municipal solid waste dumpsite in Gombe, Nigeria was determined using pollution indices like enrichment factor, contamination factor, degree of contamination, pollution load index, geo-accumulation index and ecological risks. Cadmium levels in the soil from the various sites were above the DPR target values. The other metals were within the stipulated limit set by DPR. All the pollution indices carried out show that Cd was the only metal posing an ecological risk to the local ecosystem. The human health risk carried out using the hazard quotient and total hazard index gave values less than 1, this indicate no probable health risk for children and adult living in the area of the dumpsite.

ACKNOWLEDGEMENTS

The authors are thankful to Energy Research Centre, and the Department of Soil Science, University of Nigeria, Nsukka, for the use of their research facilitiesfor some analysis.

Conflict of interests

The authors declare that there is no conflict of interest regarding the publication of this article.

REFERENCES

1. Nyangababo J.T., Hamya J.W., 1980. The Deposition of Lead, Cadmium, Zinc and Copper from Motor Traffic on BradariaEnimi and Soil along a major Bombo road. Int J Environ Stud Legol X. 1(32), 117-125.

2. Umeakuku J.M., Mba H.C., 1999. Solid waste management practices: A case Study of Anambra State. JNigInst Town Plan.12, 12-45.

3. Banat K.M., Howari F.M., Al-Hamada. A.A., 2005. Heavy Metals in Urban Soils of CentralJordan: Should We Worry about Their Environmental Risks? Environ Res.97, 258-273.

4. Zhang L.P., Ye X., Feng H., 2007. Heavy Metal Contamination in Western Xiamen Bay Sediments and Its Vicinity, China.Mar Poll Bull.54, 974-982.

5. Yu R., Yuan X., Zhao Y., Hu G., Tu X., 2008. Heavy metal pollution in intertidal sediments from Quanzhou Bay, China. J Environ Sci. 20(6), 664-669.

6. Martin D., Glass T.A, Bandeen-Roche K., Todd A.C., Shi W., Schwartz B.S., 2006. Association of blood lead and tibia lead with blood pressure and hypertension in a community sample of older adults.Am J Epidemiol.163(5), 467- 478.

7. Waalkes M.P., 2000. Cadmium Carcinogenesis in review.J Inorg Biochem. 79, 240-244.

8. Berge S.R., Skyberg K.,2003. Radiographjc evidence of pulmonary fibrosis and possible etiologic factors at a nickel refinery in Norway. Environ Monit. 5(4), 681-688.

9. Ogbuene E.B., Igwebuike E.H., Agusiegbe U.M., 2013. The impact of open municipal solid waste dumped on soil quality: A case study of Ugwuaji in Enugu, Nigeria. Brit J AdvAcad Res. 2(1), 43-53.

10. Temilola O., Oluwatoyin A., Emmanuel A., 2014. Impact Assessment of Dumpsites on Quality of near-by Soil and Underground Water: A Case Study of an Abandoned and a Functional Dumpsite in Lagos, Nigeria.Int J Sci Environ Tech. 3(3), 1004-1015.

11. Ihedioha J.N., Ukoha P.O., Ekere N.R., 2016.Ecological and human health risk assessment of heavy metal contamination in soil of a municipal solid waste dump in Uyo, Nigeria. Environl Geochem Health. DOI 10.1007/s10653-016-9830-4.

12. Reimann C., Caritat P.D., 2005. Distinguishing between natural and anthropogenic sources for elements in the environment: Regional geochemical surveys b=versus enrichment factors. Sci Tot Environ. 227, 91-107.

13. Pekey H., 2006. The distribution and sources of heavy metals in Izmit Bay surface sediments affected by a polluted stream. Mar Poll Bull. 52, 1119 -1208.

14. FRN (Federal Republic of Nigeria), 2007. Official Gazette: Legal Notice on Publication of the 2006 Census Report, 4(94) B, pp. 185-186. Lagos, Nigeria.HYPERLINK

http://www.mapsofworld.com/lat_long/nigeria-lat-long. html Date accessed 12 /09/2011 //http://www. mapsofworld.com/lat_long/nigeria-lat-long. html Date accessed 12/09/2011.

15. Iloeje N.P., 2001. A new geography of Nigeria, new revised edition. Longman Nigeria PLC.

16. Adang K.L., Nsor C.A., Tela M., 2015. Survey of avifauna of Gombe State University, Gombe, Nigeria.Int J Bio Bio Sci. 4(2), 32-36.

17. Hamdeh-Abu N.H., 2004. The effect of tillage treatments on soil water holding capacity and on soil physical properties, ISCO 2004-13th International Soil Conservation Organization Conference-Brisbane, July 2004 Conserving Soil and Water for Society: Sharing Solutions Paper 2004;No. 669, pp1-6.

18. Nwajei G.E., Gagophien P.O., 2000. Distribution of heavy metals in the sediments of Lagos lagoon. Pak J SciInd Res. 43, 338-340.

19. Muller G., 1969. Index of geo-accumulation in sediments of the Rhine river. Geol J. 2(3), 108-118.

20. Turekian K.K., Wedepohl K.H., 1961. Distribution of the elements in some major units of the earth's crust. Bull Geol Soc America. 72, 175-192.

21. Huu H.H., Rudy S., Damme A.V., 2010. Distribution and contamination status of heavy metals in estuarine sediments near CauOng harbor, Ha Long Bay, Vietnam. GeolBelgica. 13(1-2), 37-47.

22. Abrahim G.M.S., Parker R.J., 2008. Assessment of heavy metal enrichment factors and the degress of contamination in marine sediments from Tamaki Estuary, Auckland, New Zealand. Enviro Monit Assess. 136, 227-238.

23. Niencheski L.F., Windom H.L., Smith R., 1994. Distribution of particulate trace metal in Patos Lagoon Estuary (Brazil). Mar Poll Bull. 28, 96 - 102.

24. Khairy M.A., Barakat A.O., Mostafa A.R., Wade T.L., 2011.Multi-element determination by flame atomic absorption of road dust samples in Delta Region, Egypt Microch J.97, 234-242.

25. Thomilson D.C., Wilson D.J., Harris C.R., Jeffrey D.W., 1980. Problem in heavy metals in estuaries and the formation of pollution index.Hel WissMeeresunlter. 33(1-4), 566-575.

26. Sulaiman M.B., Salawu K., Barambu A.U., 2019. Assessment of Concentrations and Ecological Risk of Heavy Metals at Resident and Remediated Soils of Uncontrolled Mining Site at Dareta Village, Zamfara, Nigeria. J ApplSci EnvironManage. 22(6), 999-1003.

27. Hakanson L., 1980. An ecological risk index for Aquatic pollution control.A Sedimentological Approach. Wat Res. 14, 975-1001.

28. Lai H.Y., Hseu Z.Y, Chen T.C., Chen B.C., Guo H.Y., Chen Z.S., 2010. Health risk-based assessment and management of heavy metals-contaminated soil sites in Taiwan. Int J Environ Res Pub Health. 7(10), 3595-3614.

29. USEPA (US Environmental Protection Agency), 1998. Guidelines for Ecological Risk Assessment. Federal Register, 63(93), 26846-26924.

30. USEPA (US Environmental Protection Agency), 2001. Supplemental Guidance for Developing Soil Screening Levels for Superfunda.Sites.OSWER 9355.4-24.Office of Solid Waste and Emergency Response.

31. Ferreira-Baptista L., De MiguelE., 2005. Geochemistry and risk assessment of street dust in Luanda, Angola: a tropical urban environment. Atmos Environ.38, 4501- 4512.

32. USEPA (US Environmental Protection Agency), 2010. Integrated Risk Information System. (IRIS). United States Environmental Protection. Available online: http://www.epa.gov/iris/index.html (accessed on 4 October 2011).

33. Wang X., Wang F., Chen B., Sun F., He W., Wen D., Liu X., Wang Q., 2012. Comparing the health risk of toxic metals through vegetable consumption between industrial polluted and non-polluted fields in Shaoguan, South China.J FoodAgric Environ. 10(2), 943-948.

34. Lemly A.D., 1996. Evaluation of the hazard quotient method for risk assessment of selenium. Ecotox Environ Safe. 35, 156-162.

35. Agyarko K., Darteh E., Berlinger B., 2010. Metal level in some refuse dump soils and plants in Ghana. J Plant Soil. Environ. 56(5), 244-251.

36. Eddy N.O., Odoemelem S.A., Mbaba A., 2006. Elemental Composition of soil in some dumpsites located within IkotEkpene. Electro. J Environ AgricFood Chem. 5(3), 1349-1365.

37. Affi B.D., Emile B.B., Koffi K., Clarisse B.B., Yao G., Bernard A., Albert Y.K., Eric D., 2018. Assessment of heavy metal contamination degree of municipal open-air dumpsite on surrounding soils: Case of dumpsite of Bonoua, Ivory Coast. IntJEngr Res Gen Sci. 6(5), 28-42.

38. Uba S., Uzairu A., Harrison G.F.S., Balarabe M.L., Okunola O.J., 2008. Assessment of Heavy Metals Bioavailability in Dumpsites of Zaria Metropolis, Nigeria.Africa J Biotech. 7(2), 122-130.

39. Amusan A.A., Ige D.V., Olawafe R., 2005. Characteristics of Soil and Crop uptake of Metals in Municipal waste dump sites in Nigeria. J Human Ecol. 1(2), 167-171.

40. DPR (Department of Petroleum Resources), 2002. Environmental guidelines and Standards for the petroleum industries in Nigeria Department of Petroleum Resources, Ministry of Petroleum and Mineral Resources, Abuja, Nigeria.

41. Jafaru H.M., Dowuona G.N.N., Adjadeh T.A., Nartey E.K., Nude P.M., Neina D., 2015. Geochemical assessment of heavy metal pollution as impacted by municipal solid waste at Abloradjei waste dump site, Accra-Ghana.Res J Environ Earth Sci.7(3), 50-59.

42. Ajah K.C., Ademiluyi J., Nnaji C.C., 2015. Spatiality, Seasonality and Ecological Risks of Heavy Metals in the Vicinity of a Degenerate Municipal Central Dumpsite in Enugu, Nigeria. J Environ Health Sci Engr. 13, 15doi: 10.1186/s40201-015-0168-0.

43. Hammed A.O., Lukuman A., Gbola K.A., Mohammed O.A., 2017. Heavy Metal Contents in Soil and Plants at Dumpsites: A Case Study of Awotan and Ajakanga Dumpsite Ibadan, Oyo State, Nigeria. J Environ Earth Sci. 7(4), 11-24.

44. Chukwudi N.N., Henry D.O., Selegha A., Modupeola A.O., Vilém P., 2017. Assessment of the impacts of municipal solid waste dumps on soils and plants. Chem. Ecol. DOI: 10.1080/02757540.2017.1337101.

45. Ismat H.A., Saifeldin M.S., Abubakr M.I., Eid I.B., Khalid A.I., Sara A.M.E., Muhammad A., 2019. Contamination and human health risk assessment of heavy metals in soil of a municipal solid waste dumpsite in Khamees-Mushait, Saudi Arabia. Toxin Reviews, DOI: 10.1080/15569543.2018.1564144.

46. Ogunkunle C.O., Fatoba P.O., 2013. Pollution loads and the ecological risk assessment of soil heavy metals around a mega cement factory in south west Nigeria. Pol J Environ Std. 22(2), 487-493.

47. Ihedioha J.N., Okoye C.O.B., 2012. Cadmium and Lead Levels in Muscle and Edible Offal of Cow Reared in Nigeria. Bull Environ Contam Toxicol. 88(3), 422-427.

48. Okoye C.O.B., Ugwu J.N., 2010. Impact of environmental cadmium, lead, copper and zinc on quality of goat meat in Nigeria. Bull ChemSoc Ethiopia. 24(1), 133-138.

49. Ihedioha J.N.,Ekere N.R., Okoye C.O.B., 2013. Cadmium in locally grown rice (*Oryza sativa*) in Nigeria. Food Additives & Contaminants. Part B, 6(4), 275-278.

50. Karim Z., Qureshi, B.A., 2013. Health risk assessment of heavy metals in urban soil of Karachi, Pakistan. Hum Ecol Risk Assess. 20, 658-667.