Bima Journal of Science and Technology Vol. 2 No. 2 June, 2018 ISSN 25366041

# GEO-ACCUMULATION AND CONTAMINATION STATUS OF HEAVY METALS IN SELECTED MSW DUMPSITES SOIL IN GOMBE, NIGERIA

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## Abstract

The study assessed the extent of heavy metals contamination, determined geo-accumulation index and degree of contamination in Municipal Solid Waste (MSW) dumpsites soil in Gombe, Nigeria. Surface soil samples were collected at depth 5 - 15 cm from four selected dumpsites soil, a virgin soil away from dumps served control and were all analyzed for heavy metals (Fe, Cd, Cr, Cu, Mn, Ni, Pb and Zn) using Atomic Absorption Spectroscopy (AAS). The mean concentrations of the heavy metals (mg/kg) ranged from (105.68 - 301.16) Fe, (0.02 - 2.20) Cd, (0.65 - 2.16) Cr, (4.09 - 24.05) Cu, (40.87 - 100.08) Mn, (1.09 - 5.01) Ni, (2.01 - 9.05) Pb and (50.05 - 101.0) Zn for dumpsites soil and (105.68 ) Fe, (0.02) Cd, (0.65) Cr, (4.09) Cu, (40.87) Mn, (1.09) Ni, (2.01) Pb and (50.05) Zn for control soil sample. The concentrations of all the studied metals were within Department of Petroleum Resources (DPR) set limit, except Cd was above (0.8 mg/kg) limit set by World Health Organization (WHO) and DPR. The calculated geo-accumulation index (Igeo) shows that the soil samples from A, B, C and D dumpsites were moderately polluted with cadmium but not with other studied metals. The contamination factor ($C_f$) categorized the investigated soil samples as low contaminated with cadmium and the recorded degree of contamination ($C_d$) indicated the low degree of contamination in the soil samples which it falls under ($C_d < 8$) low degree of contamination.

**Keywords:** Contamination factor, control, heavy metal, solid waste**,** selected dumpsite, surface soil

## Introduction

Municipal solid wastes (MSW), commonly known as trash or garbage, are the solid wastes generated from different municipals. Some of these wastes have been proved to be extremely toxic and infectious (Suresh et al., 2011). Rapid increase in population and industrialisation in Nigeria have resulted in a dramatic increase in the generation of municipal solid waste (Sulaiman & Maigari, 2016). Municipal solid waste heaps dot several parts of major Nigerian cities blocking roads, alleys and pavements (Eddy et al., 2006). The unsettling problem is that dumping the waste on soil is one means which the soil quality is degraded. Continuous disposal of municipal wastes on soil may increase heavy metal concentration

(Smith et al., 1996). The amounts of metals increased with haphazard disposal of municipal waste in soils. Soils are usually regarded as the ultimate sink for heavy metals discharged into the environment (Banat et al., 2005).

Heavy metals are of considerable environmental concern due to their toxicity, wide sources, non-biodegradable properties and accumulative behaviours (Yu et al., 2008). The environmental problem of soil pollution by heavy metals has received increasing attention in the last few decades in both developing and developed countries throughout the world (Zhang et al., 2007). There need for continued and effective monitoring of these heavy metals to source and distribution in the environment is highly necessary. A complementary approach that integrated soil standard criteria, geo-accumulation index and degree of contamination is necessary in order to provide accurate assessment of heavy metal accumulation from anthropogenic sources (Zhang et al., 2009; Nobi et al., 2010).

The objective of the study is to assess the extent of heavy metals (Fe, Cd, Cr, Cu, Mn, Ni, Pb and Zn) contamination in the Municipal Solid Waste (MSW) dumpsites soil in Gombe, Nigeria, integrated with soil standard criteria, geo-accumulation index and degree of contamination.

## Materials and Methods

### Study Area

The study was carried out in Gombe metropolis, the capital of Gombe State, situated in the Northern 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 today the population is projected to be 399,531 population using 3.2% growth. The study area falls into Sudan savanna climate. It is characterized by a tropical climate with two distinct seasons; a rainy season (May-October) and a dry/harmattan season (November-April) with 28.5°C and 903 mm mean annual temperature and precipitation, respectively (Iloeje, 2001). The relative humidity ranged from 70% to 80% in August and decrease to 15 to 20% in December (Sulaiman et al., 2016).

### Soil sample collection and processing

Surface soil samples were collected from a depth of 5 - 15 cm using stainless steel trowel from four different municipal solid waste dumpsites (A=Dawaki, B=Madaki, C=Jekadafari, D=Fantami) and a control (virgin land soil) away from dumpsites in Gombe, Nigeria.

At each sampling location, five subsamples were randomly collected to make composite samples (Fig.1). A total of seventy five samples were collected for the study. A 200 g of each of the soil samples was taken in zip mouthed polyethylene bags, transported to the laboratory and stored under room temperature for pre-treatment and analyses.

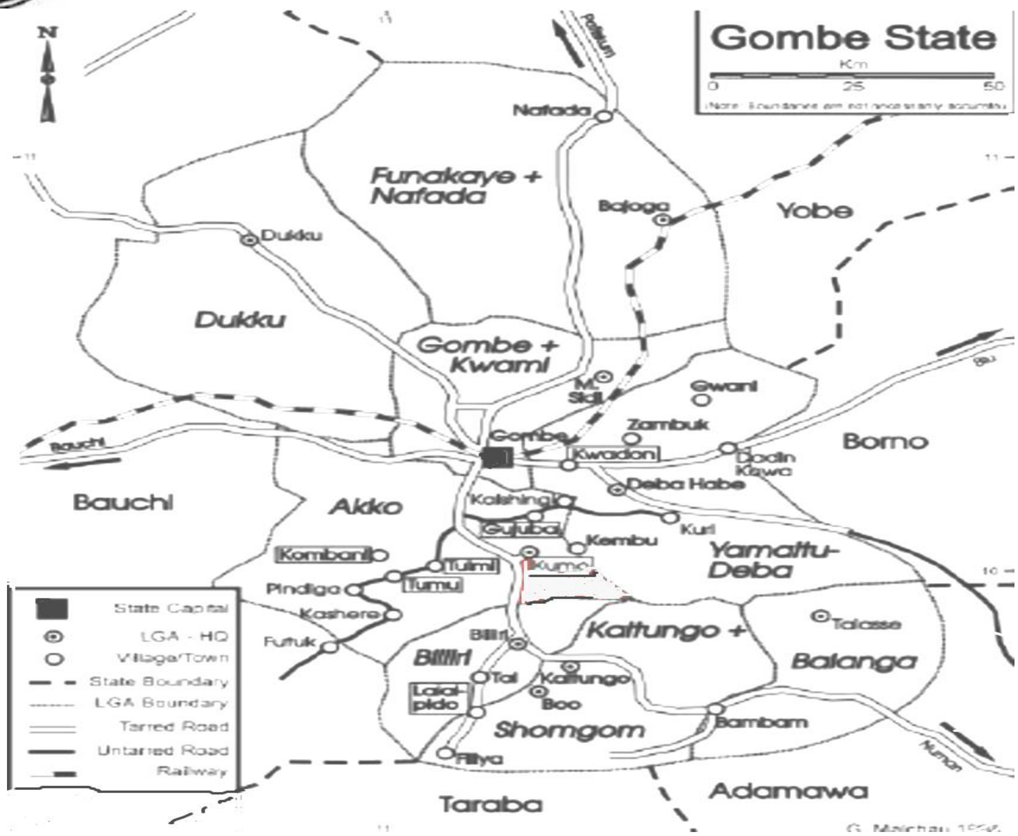


**Figure 1:** Map of the study area

## Soil physico-chemical parameters

Soil samples were analyzed for pH values, electrical conductivity, organic matter contents and soil texture. The pH and conductivity were measured in soil suspension (1:2.5 w/v dilutions) using WTW pH Electrode and conductivity meter CO150, respectively. Soil texture was determined using hydrometer test (Hamdeh, 2004) and organic matter (OM) was determined by the potassium dichromate titrimetric method (Saxena, 1989).

## Sample preparation and digestion of soil

The soil samples were air dried, grounded into a fine powder using a sterile mortar and pestle and sieved through 2 mm sieve. Samples of 2.5 g were digested in 10 mL freshly prepared aqua regia, (3:1 HCl: $HNO_3$) and placed on a hot plate at 95 °C for 1 h. The sample was then diluted to 50 mL using deionized distilled water and was left to settle overnight. The total concentrations of Fe, Cd, Cr, Cu, Mn, Ni, Pb and Zn were then determined, using Atomic Absorption Spectrometer (AAS, Unicam 969, United Kingdom).

## Quality assurance protocol

Recovery analysis was used for the validation of the digestion method. Determining metal concentrations in triplicate samples was done by un-spiked and spiked soil samples. Spiking was performed by adding 1 ml of various concentrations of the metal standard solution to 1 g of soil samples, which was later subjected to the digestion procedure. The formula for calculating the percent recoveries was:

$$\%Recovery = \frac{s-y}{z} \times 100$$

s = concentration of metal in spiked sample, y = concentration of metal in un-spiked sample, z = spiking concentration

Mean recoveries of the metals were Fe: 90±6.60%; Cd:97±4.0%; Cr:95±3.0%; Cu:86±5.6%; Ni:89±5.5%; Mn:91±4.3%; Pb:94±4.0%; Zn:92±6.0%.

## Geo-accumulation Index

The geo-accumulation index ($I_{geo}$) was introduced by Müller (1969) and has been widely employed in European trace metal studies (Ji et al., 2008). This method assesses the metal pollution in terms of seven enrichment classes ranging from background concentration to very heavily polluted (0 to 6), and estimated as follows:

$$I_{geo} = Log_2 \left[\frac{C_n}{1.5\,B_n}\right] \quad \ldots\ldots (1)$$

Where $C_n$ metal is the measured concentration of the examined heavy metal in the soil sample and $B_n$ is the geo-chemical background concentration or reference value of the metal n. The factor 1.5 is introduced to minimise the effect of possible variations in the background or control values which may be attributed to lithogenic variation in the soil. The world average elemental concentration in mg/kg (Fe = 47200, Cd = 0.30, Cu = 45, Cr = 90, Mn = 850, Ni = 68, Pb = 20 and Zn = 95) reported by Turekian and Wedepohl (1961) in the earth's were used as reference in this study. According to Huu *et al*., (2010), seven contamination classes are used to define the degree of metal pollutants in soils based on the increasing value of the index of geo-accumulation as follows:

Igeo < 0 means unpolluted; 0 ≤ Igeo < 1 means unpolluted to moderately polluted; 1 ≤ Igeo < 2 means moderately polluted; 2 ≤ Igeo < 3 means moderately to strongly polluted; 3 ≤ Igeo < 4 means strongly polluted; 4 ≤ Igeo < 5 means strongly to very strongly polluted; Igeo > 5 means very strongly polluted.

## Contamination factor/Degree of contamination

The contamination factor was derived by employing the model by Lacatusu (2000).

$$C_f = \frac{C_n}{C_o} \quad \ldots\ldots (2)$$

Degree of contamination ($C_d$) is defined as the sum of all contamination factors.

$$C_d = \sum_{i=0}^{n} Cf \quad \ldots\ldots (3)$$

Where $C_f$ is a contamination factor, $C_n$ is the metal content in the sediments, $C_o$ is the geo-chemical background concentration or reference value of metal and $C_d$ is degree of contamination.

The target (background) value is reference value of metals DPR (2002) for maximum allowable concentration of metals in Nigeria soil (Fe = 5000, Cd = 0.8, Cu = 36, Cr = 100, Mn = 476, Ni = 35, Pb = 85, Zn = 140)

in mg/kg. The following terminology was used to describe the contamination factor:
Cf < 1 low contamination; 1 < Cf < 3 moderate contamination; 3 < Cf < 6 considerable contamination; Cf > 6 very high contamination; whereas, Degree of contamination ($C_d$) was, $C_d$ < 8 low degree of contamination; 8 < $C_d$ < 16 moderate degree of contamination; 16 < $C_d$ < 32 considerable degree of contamination; $C_d$ > 32 very high degree of contamination.

## Results and Discussion

### Physico-chemical parameters of soil samples

Statistical analysis (means and standard deviation) for physico-chemical characteristics of the soil samples in the study are presented in Table 1. The pH ranged between 7.55 to 8.02 and 7.30 in control soil, which suggests that sub-alkaline conditions for all soil samples in this study. The higher pH level in the dump sites compared to control has been as a result of liming materials on the solid wastes. The results recorded in the study were also higher than 7.2 to 7.8 pH reported by Adedosu et al. (2013) from land fill soil in Ojota, Lagos, Nigeria. The electrical conductivity in A dumpsite soil sample recorded (567 $\mu Scm^{-1}$) a higher value than the other sites, while lowest value was (189 $\mu Scm^{-1}$) recorded at control site. This may be as result of high content of soluble salts in the soil. The soil at the dump site has considerable clay contents and thus it retained nutrients in the soils. The organic matter content ranged between 4.89 to 5.46 %, the organic matter recorded in the dumpsites was higher than 0.35 % of the control site. This might due to the composition of the solid wastes which were mostly comes from household and also the activities of microorganisms in the decomposition of these wastes. The result of organic matter recorded in this study is in line with high organic matter content in dumpsite, reported by Osei *et al*. (2016) and Oyedele *et al*. (2008) in their studies.

### Heavy metal distribution in the soil samples

Statistical analysis (mean and standard deviation) for heavy metals in the soil samples are presented in Table 2. The mean concentrations were ranged as follows: Fe (99.89 - 301.16mg/kg), Cd (1.53 - 2.20 mg/kg), Cr (1.65 - 2.16 mg/kg), Cu (2.4.05 - 18.28 mg/kg), Mn (79.85 - 100.08 mg/kg), Ni (3.04 - 5.01 mg/kg), Pb (6.80 - 9.05 mg/kg) and Zn (95.60 - 101.0 mg/kg) were recorded in the dumpsites soil (A, B, C, and D), while the control soil (E) recorded.

**Table 1:** Physico-chemical parameters of soil samples

| Parameters | A | B | C | D | E |
|---|---|---|---|---|---|
| pH | 7.55 ± 0.10 | 8.02 ± 0.13 | 8.00 ± 0.14 | 7.67 ± 0.11 | 7.30 ± 0.10 |
| EC $\mu Scm^{-1}$ | 440 ± 15.0 | 567 ± 15.2 | 536 ± 16.1 | 546 ± 15.9 | 189 ± 11.6 |
| OM % | 4.89 ± 1.21 | 5.06 ± 1.02 | 5.46 ± 1.08 | 5.19 ± 1.21 | 0.35 ± 0.98 |
| Sandy % | 43.23 ± 0.98 | 51.42 ± 1.01 | 45.24 ± 0.97 | 50.01 ± 1.00 | 53.04 ± 0.89 |
| Silt % | 24.00 ± 0.09 | 23.53 ± 0.08 | 19.30 ± 0.08 | 25.20 ± 0.07 | 24.10 ± 0.09 |
| Clay % | 32.77 ± 0.45 | 25.05 ± 0.38 | 35.46 ± 0.42 | 24.79 ± 0.29 | 22.86 ± 0.30 |

EC=Electrical conductivity, OM=Organic matter, A=Dawaki, B=Madaki, C=Jekadafari, D=Fantami, E=Control

Fe (105.68 mg/kg), Cd (0.02 mg/kg), Cr (0.65 mg/kg), Cu (4.09 mg/kg), Mn (40.87 mg/kg), Ni (1.09 mg/kg), Pb (2.01 mg/kg) and Zn (50.05 mg/kg). General trend of the metals were Fe>Zn>Mn>Cu>Pb>Ni>Cd>Cr. The lowest concentrations of all the studied metals were recorded in the control sample. Iron recorded the highest concentrations in all the studied sites. The high concentration of iron may be due to iron deposition through metals in the dumpsite. It's also reported that iron is the most abundant element in Nigerian soil (Amusan et al., 2005). Low concentration of chromium (1.65 mg/kg) was recorded in the A dumpsite soil sample, and highest concentration was recorded in B dumpsite soil sample (2.16 mg/kg). The content of chromium recorded in this study was higher than 0.30 mg/kg reported by Adaikpoh (2013) in soil from waste dumpsites within Imoru, Nigeria. The high chromium contents in this study could be due to wastes consisting of discarded such as plastic materials, empty paint containers and coloured polythene bags. The highest concentration of cadmium was recorded in A dumpsite soil sample (2.20 mg/kg) and lowest concentration of cadmium was recorded in B dumpsite soil sample (1.53 mg/kg). This variation of the metals may depend on the types and the compositions of waste at the dumpsites. The concentrations of all metals studied were within the limit set by DPR, except Cd in samples from dumpsites were above (0.8 mg/kg) limit set by WHO and DPR. Anthropogenic release of Cd in the studied soil samples could be as a result to the rise in disposing of cadmium containing substances such as batteries in phones and torches, plastics and other electronic gadgets, to the municipal waste dumpsite. The Cd levels in this study were higher than 0.73mg/kg reported in dumpsite soil in Abloradjei, Accra, Ghana (Jafaru et al., 2015).

**Table 2:** Heavy metal distribution in the soil samples (mg/kg)

| Parameters | A | B | C | D | E |
|---|---|---|---|---|---|
| Fe | 301.16 ± 12.32 | 275.00 ± 13.00 | 298.30 ± 11.89 | 199.89 ± 12.21 | 105.68 ± 10.86 |
| Cd | 2.200 ± 1.02 | 1.530 ± 1.02 | 1.920 ± 1.04 | 2.010 ± 1.01 | 0.020 ± 0.98 |
| Cr | 1.650 ± 0.67 | 2.160 ± 0.74 | 1.890 ± 0.71 | 1.750 ± 0.59 | 0.650 ± 0.31 |
| Cu | 18.28 ± 3.80 | 24.05 ± 3.29 | 19.35 ± 2.98 | 20.00 ± 4.21 | 4.090 ± 0.02 |
| Mn | 98.00 ± 6.01 | 100.08 ± 6.71 | 79.85 ± 5.89 | 85.010 ± 5.92 | 40.87 ± 3.89 |
| Ni | 3.080 ± 0.07 | 3.040 ± 0.08 | 5.010 ± 0.07 | 5.000 ± 0.07 | 1.090 ± 0.02 |
| Pb | 8.600 ± 1.76 | 6.800 ± 1.00 | 9.050 ± 1.21 | 8.090 ± 1.12 | 2.010 ± 0.08 |
| Zn | 100.01 ± 7.00 | 98.50 ± 6.87 | 95.60 ± 6.96 | 101.0 ± 6.00 | 50.05 ± 6.98 |

A=Dawaki, B=Madaki, C=Jekadafari, D=Fantami, E=Control

But lower than 9.05mg/kg reported by Ihedioha et al. (2016) in dumpsite soil from Uyo, Nigeria, and also the nickel recorded in this study were lower than those reported in dumpsite soils in Uyo, Nigeria and Accra, Ghana respectively (Ihedioha et al., 2016) and (Jafaru et al., 2015). The concentration of heavy metals can also be affected by physicochemical properties of the soils. The higher contents of organic matters of soil from dumpsites lead to the high absorbance of heavy metals compared control site due a large number of functions which could synthesize with heavy metals ions under certain conditions.

**Geo-accumulation index**

The result of the geo-accumulation index of the soil samples was presented in Figure 2. The dumpsites soil samples A, B, C and D recorded Cd Igeo of 1.38, 1.07, 1.26 and 1.30, respectively, were fall under moderately polluted range while other studied metals (Fe, Cr, Cu, Mn, Ni, Pb and Zn) fall under unpolluted range in all the studied samples. The Igeo results recorded in this study were similar to the results reported by Adaikpoh (2013) moderately polluted in soil from waste dumpsites in Imoru, Nigeria and Onyedika (2015) moderately to strongly polluted with Cd at a dumpsite in Bauchi, Nigeria. But lower than the results reported by Ihedioha et al. (2016) extremely polluted with cadmium at dumpsites in Uyo, Nigeria.

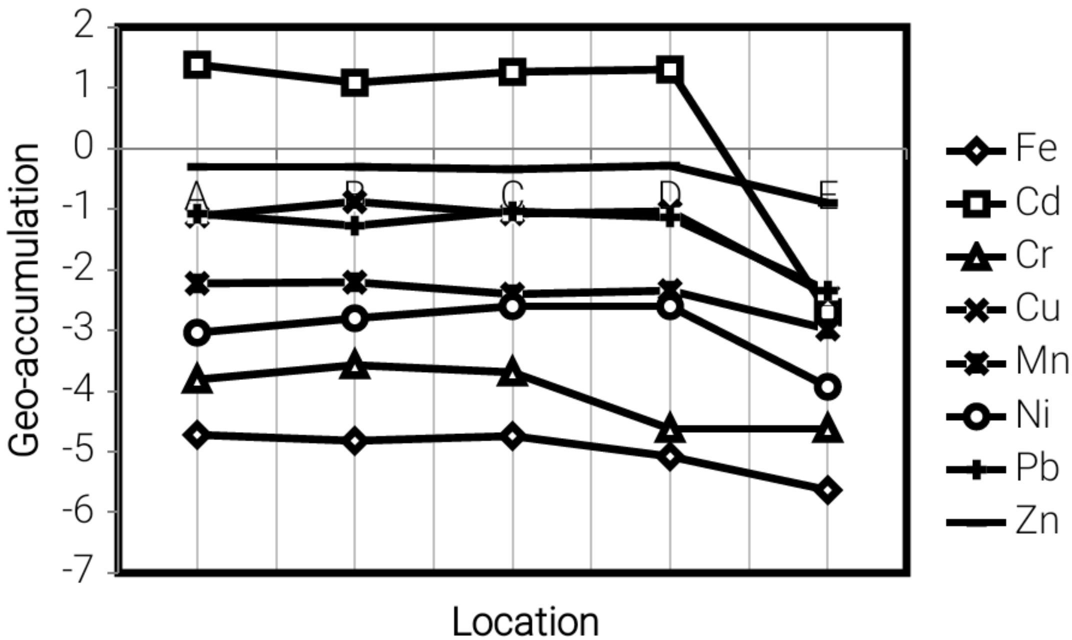


**Figure 2:** Geo-accumulation index (Igeo) of the metals in soil samples

**Contamination factor/Degree of Contamination**

The contamination factor and degree of contamination of studied metals in all soil samples are presented Table 3. The results of contamination factor (Cf) indicated the low contamination ($C_f < 1$) for all the studied metals in the soil samples except Cd, which recorded moderate contamination ($1 < C_f < 3$) in soil samples A, B, C and D. The recorded degree of contamination ($C_d$) indicated low degree of contamination in all the studied sites, fall under ($C_d < 8$).

**Conclusion**

This study was conducted to assess the extent of heavy metals contaminationdetermined geo-accumulation index and degree of contamination in selected Municipal Solid Waste (MSW) dumpsites soil in Gombe, Nigeria. The result of the study revealed there is an evidence of relative increase in the mean concentrations of heavy metals in soil samples from the dumpsites compared with control sample. All the integrated soil standard criteria carried out shows that Cd is the only metal that is above standard limit and posing a higher contamination to the local environment.

**Table 3:** Contamination factor ($C_f$) / Degree of contamination of the metals in soils ($C_d$)

| | $C_f$ | | | | |
|---|---|---|---|---|---|
| Parameters | A | B | C | D | E |
| Fe | 0.0602 | 0.0550 | 0.0596 | 0.0399 | 0.0211 |
| Cd | 2.7500 | 1.9125 | 2.4000 | 2.5125 | 0.0250 |
| Cr | 0.5077 | 0.6680 | 0.5375 | 0.5555 | 0.1136 |
| Cu | 0.0165 | 0.0216 | 0.0189 | 0.0175 | 0.0065 |
| Mn | 0.2059 | 0.2103 | 0.1677 | 0.1785 | 0.0859 |
| Ni | 0.0880 | 0.1154 | 0.1431 | 0.1425 | 0.0311 |
| Pb | 0.1012 | 0.0800 | 0.1065 | 0.0952 | 0.0236 |
| Zn | 0.7144 | 0.7036 | 0.6829 | 0.7214 | 0.3575 |
| $C_d$ | 4.4439 | 3.7664 | 4.1162 | 4.2631 | 0.6643 |

A=Dawaki, B=Madaki, C=Jekadafari, D=Fantami, E=Control

## Conclusion

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