



Ecological Risk Assessment of Some Heavy Metals in Roadside Soils at Traffic Circles in Gombe, Northern Nigeria

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ABSTRACT: The study evaluated the levels of some heavy metals in the roadside soils at different traffic circles using geo-accumulation index, ecological risk and Hakanson method to assess the overall ecological risk and identify ecological potential risk of heavy metals pollution. The top soil samples were collected at three different traffic circles from edge and at 50 m distance from the roadside, and analysed for heavy metal (Pb, Cd, Cu and Zn) using atomic absorption spectrophotometer. The mean concentrations of heavy metals (mg/kg) ranged from (15.0 - 45.07) Pb, (0.35 - 2.60) Cd, (19.05 - 38.0) Cu and (58.10 - 101.0) Zn. The abundance of metals was found in declining order: Zn > Pb > Cu > Cd. The metals concentrations were found to be higher in the soil samples from edge due to high traffic volume and human activities, and there was significantly decrease in concentration with increase in roadside distance. The Geo-accumulation index (I_{geo}) examined in this study revealed that soil samples from edge and 50 m distance from the roadside were polluted with cadmium. Ecological risk assessment carried out showed that the metals posed low ecological risk and cadmium contributed 66.63 - 94.21% of the total potentially ecological risk.

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Public motor roads affects natural environment to a large extent because automobile act as line sources of heavy metal pollutants (Poszyler and Czemiak, 2007). Heavy metals in the soil can generate airborne particles and dust which may affect the quality of air (Gray *et al.*, 2003). Emission from heavy traffic was reported to contain Lead, Cadmium and Zinc which are present in fuel as anti-knock agent (Suzuki *et al.*, 2008; Atayese *et al.*, 2009). Various researchers have found that the concentrations of the metals Pb, Cu, Zn and Cd decrease rapidly within 10 to 50 m from the roadsides (Joshi *et al.*, 2010; Pagotto *et al.*, 2001).

Roadside soils often show a high degree of heavy metal contamination that can be attributed to motor vehicles. In recent years, considerable attention has been paid to the vehicular exhaust and road dust/soil, the pollution of the roadside soils by heavy metals from automobile source is a serious environmental issue (Ma *et al.*, 2009; Aslam *et al.*, 2011; Lu *et al.*, 2012). Heavy metal originates from different sources; traffic density and their natural presence in the soil. Therefore, heavy metal contamination in roadside has been a worldwide environmental concern with its potential ecological effect (Hu *et al.*, 2017).

Ecological risk assessment evaluates the risk posed by pollutants in soils, and helps in the interpretation of soil quality (Prakruthi and Raju, 2017). Ecological risk factor (E_i) is used for evaluation of anthropogenic influence on soil and sediment, many studies were performed using these approaches (Mathias *et al.*, 2016). The risk assessment of heavy metals would provide a certain theory support for risk management; these methods used to evaluate the ecological risk posed by heavy metals in soil include calculation of geo-accumulation and potential ecological risk index (Hakanson, 1980).

This current study aims to evaluate the levels of some heavy metals in the roadside soils at different traffic circle in Gombe metropolis with a view of providing information on the extent of the pollution and overall ecological risk of metals in the soil to the local environment.

MATERIALS AND METHODS

Study Area: The study area consists of three traffic circles 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 km² and about

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399,531 estimated population (Figure 1). The study area falls into Sudan savanna climate. The climate of the area is tropical with dry/harmattan season (November-April) and rainy season (May-October) with 18 °C to 39 °C, with an average annual rainfall of 850-954 mm (Iloeje, 2001). The relative humidity ranged from 70% to 80% in August and decrease to 15 to 20% in December (Sulaiman *et al.*, 2016).

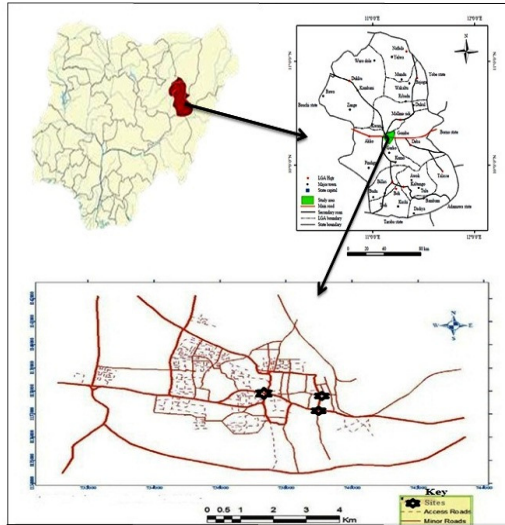


Fig 1: Map of Gombe road network showing the study area

Soil sample collection and processing: Soil samples were collected from top soil (0 - 10 cm) using stainless steel trowel at three different traffic circles from edge and 50 m distance from the roadside. At each sampling location, four subsamples were randomly collected to make a composite sample. 100 g of each composite sample were collected into zip mouthed polyethylene bags and transported to the laboratory, stored at room temperature for pre-treatment and analyses.

Sample preparation and digestion of soil: The air dried soil samples were grinded with an agate mortar and sieved through 1mm mesh standard sieve. 0.5 g of each of the sample were digested in 20 ml freshly prepared aqua-regia (1:3 HNO₃:HCl) on a hot plate for 3hrs, then evaporated and diluted with 50 mL of distilled water to determine the concentration of Pb, Cd, Cu and Zn, were all determined with atomic absorption spectrophotometer (AAS) (AA6300, Shimadzu, Japan). All the samples analysis was done in three replicates.

Quality assurance procedure: Precision and accuracy of the analytical procedure was carried out by recovery experiment. This was done by determining metal concentrations in triplicate samples of un-spiked and

spiked soil samples. Spiking was performed by adding 1 mL of various concentrations of the metal standard solution to 0.5g of soil sample, which was later subjected to the digestion procedure. The formula for calculating the percent recoveries was:

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

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

The percentage recoveries lay within the range 89.8 - 96.70%, this indicating good accuracy and precision.

Pollution Indices: Pollution indices are tools use to analyses environmental data to decision makers and for the public. In this study the following indices; geo-accumulation index and ecological risk assessment were employed to measure the extent of pollution.

Geo-accumulation Index: Geo-accumulation Index was proposed by (Muller, 1969). This method assesses the metal pollution, ranging from background concentration to very heavily polluted, as follows:

$$I_{geo} = \text{Log}_2 \left[\frac{C_n}{1.5 B_n} \right] \dots \dots \dots (1)$$

Where C_n metal is the measured concentration of the examined heavy metal in the soil sample and B_n is the geochemical background concentration or reference value of the metal n. The factor 1.5 is introduced to minimize the effect of possible variations in the background or control values which may be attributed to lithogenic variation in the soil. The background value is reference value of metals by (DPR, 2002) were used, for maximum allowable concentration of metals in Nigeria soil (Pd = 85, Cd = 0.8, Cu = 36 and Zn = 140) in mg/kg. 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: I_{geo} < 0 means unpolluted; 0 ≤ I_{geo} < 1 means unpolluted to moderately polluted; 1 ≤ I_{geo} < 2 means moderately polluted; 2 ≤ I_{geo} < 3 means moderately to strongly polluted; 3 ≤ I_{geo} < 4 means strongly polluted; 4 ≤ I_{geo} < 5 means strongly to very strongly polluted; I_{geo} > 5 means very strongly polluted (Huu *et al.*, 2010).

Ecological Risk Assessment: Ecological risk assessment is practice to determine the nature likelihood effects of our actions on living and the environment. The assessment of ecological risks of

heavy metals in soil samples was done using the Ecological Risk factor E_r^i and Potential Ecological Risk Index (R_i) proposed by (Hakanson, 1980), express as follows;

$$E_r = T_i \times \left(\frac{C_n}{C_o}\right) \dots\dots\dots (2)$$

Where E_i is ecological risk factor, T_i is toxic response factor of a certain metal. The values for each metal is in the order of $Zn=1 < Cr=2 < Cu=Ni=Pb=5 < Cd=30$. C_n is the metal content in the soil and C_o is a background values (reference value of metals in soil). The following terminology are used to described the potential ecological risk factor, $E_i < 40$ indicate low potential ecological risk, $40 < E_i < 80$ moderate potential ecological risk, $80 < E_i < 160$ considerable potential ecological risk, $160 < E_i < 320$ high potential ecological risk and $E_i > 320$ very high potential ecological risk.

$$R_i = \sum E_r^i \dots\dots\dots (3)$$

Where R_i is potential ecological risk calculated as the sum of ecological risk factor for heavy metals in soil. E_i is ecological risk factor. The following terminology are used to described the potential ecological risk index; $R_i < 150$ low ecological risk, $150 \leq R_i < 300$ moderate ecological risk, $300 \leq R_i < 600$ considerable ecological risk, and $R_i > 600$ very high ecological risk.

Table 1: Description of the traffic circle studied

Site code	Name of site
TTC	Town traffic circle
50 m (TTC)	50 m distance from TTC
MTC	Market traffic circle
50 m (MTC)	50 m distance from MTC
UTC	Union bank traffic circle
50 m (UTC)	50 m distance from UTC

RESULTS AND DISCUSSION

Heavy metal content in the soil samples: The results of heavy metals as well as the statistical analysis of soil samples are presented in (Table 2). The abundance of metals was in declining order: $Zn > Pb > Cu > Cd$. The mean concentration of Pb ranged from 15.0 - 45.07 mg/kg, Cd 0.35 - 2.60 mg/kg, Cu 19.05 - 38.0 mg/kg

and Zn 58.10 - 101.0 mg/kg in all the studies sites. The highest mean concentration of Pd (45.07 mg/kg) and Cd (2.60 mg/kg) were recorded from edge sample at TTC. The slow movement of vehicles in the heavy traffic of the traffic circle may attribute for the high level of metals in the roadside soil. The high mean concentration of Cu (26.2 - 67.0 mg/kg), Pb (18.1 - 66.0 mg/kg) Zn (26.3 - 123.0 mg/kg) and Cd (0.63 - 2.85 mg/kg) was also reported by Mafuyai *et al.*, (2015) in roadside soil at Jos metropolitan area, Nigeria. This agrees with high concentration of Pb, Cu, Cd and Zn recorded for samples from edge of roadside compare to distance from 50 m in this study. The results of Pb (15.1 - 650 mg/kg) reported by Onianwa (2001), was higher than the Pb concentration recorded in the soil samples from edge of roadside while the Cd (0.02 - 2.71 mg/kg) concentration in the present study were higher than the values reported. The soil sample from edge roadside at MTC recorded the highest concentration of Zn (101.0 mg/kg) while soil sample at UTC recorded highest the concentration of Cu (38.00 mg/kg) and lowest concentration of Zn and Cu was recorded at 50 m distance UTC (58.10 mg/kg) and at 50 m distance MTC (18.50 mg/kg) respectively. Taofeek and Tolulope (2012), reported the mean concentration of Zn in roadside soil at Ogbomoso was lower than the Zn concentration recorded in the soil from edge. Abechi *et al.*, (2010) also reported the mean concentration of Cu (1.3 - 2.28 mg/kg) in roadside soils of major streets in Jos metropolis, Nigeria, was lower than the values recorded in this study. The concentration of metals (Pb, Cu and Zn) in the soil samples from edge of roadside and 50 m distance were below limit set by Department of Petroleum Resource (DPR, 2002) and World Health Organization (WHO, 1996). However, the content of Cd from edge samples at TTC, MTC and UTC were all above the set limit of (0.8 mg/kg) by (DPR) and (WHO), but were below at 50 m distance. Anthropogenic release of cadmium in the soil could be as results of vehicular emissions, lubricating, natural sources as non-degradable and tires used on the rough surfaces of the roads. The concentration of metals in the soil samples from edge of roadside soil was higher due to traffic volume and human activities, and there is significantly decrease in metals concentration with increase in roadside distance.

Table 2: Heavy metals content in the roadside soil samples (mg/kg)

Metals	TTC	50 m (TTC)	MTC	50 m (MTC)	UTC	50 m (UTC)
Pb	45.07 ± 0.92	20.20 ± 0.64	33.00 ± 0.10	19.20 ± 0.09	28.80 ± 0.08	15.00 ± 0.09
Cd	2.60 ± 0.01	0.61 ± 0.02	2.10 ± 0.03	0.55 ± 0.01	1.99 ± 0.02	0.46 ± 0.03
Cu	38.00 ± 0.10	21.05 ± 0.09	31.30 ± 0.08	18.50 ± 0.07	33.00 ± 0.06	19.05 ± 0.04
Zn	96.60 ± 0.84	60.69 ± 0.68	101.0 ± 0.92	71.00 ± 0.43	85.50 ± 0.55	58.10 ± 0.82

Pollution indices: The results of the geo-accumulation index of the soil samples were presented in (Figure 2). The result revealed that all studied the metals in respect of all the studied sites fall under unpolluted range; except Pb in some samples and Cd in all the studied sites. The I_{geo} of Pb from edge of roadside soil at TTC and MTC ranged from unpolluted to moderately polluted. The I_{geo} results in this study were similar to the results reported by Taofeek and Tolulope (2012), moderately polluted with Pb in roadside soil from Ogbomoso, South West Nigeria. The I_{geo} of Cd ranged from unpolluted to moderately polluted in samples 50 m distance at TTC, MTC and UTC respectively, and moderately to strongly polluted at edge samples.

The ecological risk assessment results of the heavy metals were summarized in (Table 3). Based on the assessment, the potential ecological risk of the metals were in the following trend $Cd > Cu > Pb > Zn$. It was found that the values obtained for Pb, Cu and Zn were below 40 in all the studied sites, hence indicating low potential ecological risk. The value for Cd from edge sample at UTC was within the range of moderate potential ecological risk while samples from edges at MTC and TTC recorded values were within the considerable potential ecological risk. This indicated that Cd posed a potential risk to the local ecosystem. However, in the other locations were below 40, indicating low potential ecological risk. R_i could characterize sensitivity of local ecosystem to the toxic metals and represents the ecological risk resulting from the overall contamination (Yisa *et al.*, 2012). In order to qualify the overall potential ecological risk of the detected metals in the soil, R_i was calculated as the sum of all four risk factors (Table 3). The R_i ranged from 19.706 - 103.487, in respect to all the studied sites. The R_i values in all samples were lower than 150, indicating low ecological risk. The R_i shows that Cd contribute 66.63 - 94.21% to the overall potential ecological risk. It could be concluded that the ecological risk in this study was primarily contributed by Cd. The results recorded in this study were higher than the results reported by Gu *et al.*, (2012) Cd which range from 58.08 - 75.62% with mean rate of 61.39% in Roadside Soils on Different Operated Times along the Lianyungang-Horgas Highway, China. But lower than the results reported by Prakruthi and Raju (2017), of high ecological risk in Roadside Soils of Mysuru, Karnataka, India.

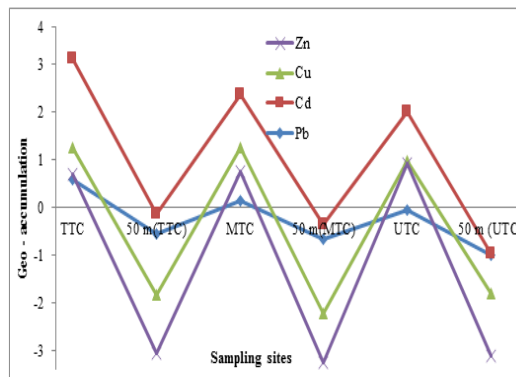


Fig 2: Geo-accumulation index, I_{geo} for heavy metals of the roadside soil samples

Table 3: Ecological Risk factor E_r^i and Potential Ecological Risk Index R_i for heavy metals of the roadside soil samples

Metals	E_r^i					
	TTC	50 m (TTC)	MTC	50 m (MTC)	UTC	50 m (UTC)
Pd	2.651	1.206	1.941	1.130	1.941	0.883
Cd	97.50	22.88	82.88	20.63	74.63	13.13
Cu	2.646	2.924	4.347	2.569	4.584	5.278
Zn	0.690	0.434	0.721	0.507	0.611	0.415
$R_i = \sum E_r^i$	103.487	27.444	89.889	24.836	81.766	19.706

Conclusion: Roadside soils from three different traffic circles in Gombe, Nigeria were examined for Pb, Cd, Cu and Zn. The results of the metals shows that the abundance of metals were in declining order: $Zn > Pb > Cu > Cd$. The result generally revealed that the concentration of the metals decrease with increase in roadside distance due to traffic volume and human activities. All the pollution indices carried out shows that Cd is the only metal that is above the standard limit and posing a contamination to the local environment. Ecological risk assessment showed low ecological risk index with values less than $R_i < 150$. Regular monitoring should be conducted to ensure suitable management of the urban environment and reduction of traffic related contamination of soil in high traffic areas in Gombe, Nigeria.

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