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Concentration of Heavy Metals in Soil and Plants along Mubi-Gombi, Roadside, Adamawa State, Nigeria

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Abstract

This study was aimed at determining the elemental concentrations of heavy metal pollutants that may be present in soil and plant samples along Mubi – Gombi roadside Adamawa state, Nigeria. The concentrations of selected heavy metals (Zn, Cr, Mn, Ni and Cu) along Mubi - Gombi roadside were analyzed. Samples of roadside surface soil and plant were collected from six towns; these include Mubi, Mararaba, Makera, Kala'a, Hong and Gombi. Samples of soil and plant were taken in each town at a distance of 5 m, 10 m and 15 m away from the edge of the road. The samples were digested using aqua regia digestion method. Subsequently, the concentration of these metals was analyzed using Atomic Absorption Spectrophotometer. The result revealed that Zn, Cr, Mn, Ni and Cu were present in the studied soil and plant samples. The mean concentrations ranged from Zn (9.19 ± 1.31 –13.40 ± 3.01 mg/kg) Cr (0.01 ± 0.00 – 0.03 ± 0.01 mg/kg), Mn (11.02 ± 2.51 –13.52 ± 3.32 mg/kg), Ni(0.04 ± 0.01- 0.12 ± 0.04 mg/kg), and Cu(0.07 ± 0.02 - 0.26 ± 0.08 mg/kg) in the soil samples, while the mean concentration in plant leave samples ranged from Zn (7.10 ± 1.21- 11.28 ± 2.81 mg/kg), Cr (0.01 ± 0.00 - 0.02 ± 0.00 mg/kg), Mn (9.43 ± 1.82 - 12.81 ± 2.53 mg/kg), Ni (0.01 ± 0.00 - 0.09 ± 0.02 mg/kg) and Cu (0.03 ± 0.01 - 0.19 ± 0.07 mg/kg). The concentration of Mn and Ni exceeded the permissible limit of WHO. While the concentration of Zn, Cr and Cu were found to be within WHO limit. The high levels of Mn and Ni indicate the potential health risk for human. The high level of these metals might be due to anthropogenic activities. However, the values of these heavy Metals decreased with increasing distance away from the edge of the road. The result of the transfer factor showed that only Mn at Mubi has the highest value of 1.07 which shows that plants were enriched by Mn from the soil, followed by Ni at Mubi and Cr at Gombi with the value of 1.00. While the values of Zn and Cu was below 1.00 at all the studied sites. There was strong positive correlation for all the metals studied which implies that plants absorb the metals from the soil through their root. It could also mean that roadside soil and plants contamination by metals originated from a common anthropogenic source; with probably automobiles as a major common source. Therefore economic plants should not be planted along the highway to avoid heavy metal contamination.

Keywords: Heavy Metal; Plants; Soil; Automobile Emission; Atomic Absorption Spectrophotometer.

Introduction

The problem of environmental pollution due to toxic metals is of major concern in the world today. Heavy metals occur naturally in the soil environment from the pedogenetic processes of weathering of parent materials at levels that are regarded as trace (<1000 mg·kg−1) and rarely toxic (Qasem *et al*., 1999; Abdulmajeed *et al*., 2013).

Heavy metals, which are natural components of the environment mainly in combined forms, are being added to the soil through direct or indirect consequences of anthropogenic activities such as industrial and disposal of urban waste; addition of manures, sewage sludge, fertilizers and pesticides; mining and smelting of non-ferrous metals and metallurgical, spent engine oil, heavy metal emission from vehicles etc to soils (Anhwange *et al*., 2009; Iniobong *et al*., 2012; Adah *et al*., 2013).Metal pollution of roadside soil and plant arising from industrial activities, vehicular emissions, and waste disposal sites are well documented (Joshua *et al*., 2015; Fan *et al*., 2012 Mandal and Voutchkov 2011; Addo and Darko 2012).

The mechanisms of heavy metal emission from vehicles consist of, engine oil consumption, fuel consumption, tire wear, brake wear, and road abrasion (Taofeek *et al.*, 2012). Engine oil consumption is responsible for the largest emission for Cd, fuel consumption for the emissions of Pb, tire wear contributes the most important emission for Zn, and brake wear is the most important source of emissions for Cu and Pb (Qasem *et al*., 1999). Though the use of unleaded gasoline has caused a subsequent reduction in fuel emissions of Pb, it may still occur in exhaust gas as well as from worn metal alloys in the engine. Bitumen and mineral filler materials in asphalt road surfaces contain different heavy metal species, including Cu, Zn, Cd, and Pb (Radmila *et al.,* 2013). Heavy metals can be transported into the roadside soils and plants by atmospheric precipitation or road runoff (Fan *et al*., 2012).

The risk posed by heavy metals to food safety and the environment are of great concern to governments and society in many countries. Heavy metal pollution in roadside agricultural soils and plant is becoming serious with the rapid industrialization and urbanization in developing countries (Fan *et al*., 2012). Soil contamination by heavy metals can cause long term problems on the biogeochemical cycle, which may affect soil functioning systems, leading to changes in soil fauna (Papa *et al*., 2010). In plants, excessive Pb alters normal metabolic pathways by disrupting specific cellular enzymes and may also inhibit the photosynthetic ability of plants (Ijeoma *et al*., 2011; Kumar *et al*., 2018). In humans, trace metals such as Pb may affect the brain and cause retarded growth, especially in children. On a general note, excessive levels of heavy metals may result in the induction of oxidation stress, damage to DNA, and disturbances in the biosynthetic pathways (Ceccatelli *et al*., 2010).

The present study was carried out to investigate the concentrations of heavy metals from soils and plants collected along Mubi-Gombi road. Also Pearson correlation was used to determine the relationship between the concentration of heavy in the soil and plants.

Materials and Method

Study Area

Adamawa state is located at the North Eastern part of Nigeria. It lies between latitude 70^0 and 110 N of the equator and between longitude 110^0 and 140 E of the Greenwich meridian. It shares boundary with Taraba State in the South and West, Gombe State in its North West and Borno to the North, Adamawa State has an international boundary with the Cameron Republic along its Eastern border. The State covers the land area of about 3874 km^2 (Adebayo and Tukur, 1999).

Six major towns along Mubi –Gombi highway were selected for soil and fresh plant leaf sample. This major road was chosen for the study, because it has the heaviest traffic, these towns include: Mubi, Mararaba, Makera, Kala'a, Hong and Gombi. A total of eighteen (18) surface soil samples were randomly collected three from each town with the aid of stainless steel spoon , washed with soap and rinsed with distilled water after each sampling, at variable distance from the edge of the road 5 m, 10 m, and 15 m away from the road. The soil sampling spots were cleared of debris before taking the sample (Chimuka *et al*., 2005). About 20g of soil samples in each town were collected randomly from every sample location along Mubi – Gombi highway. The collected soil samples were placed in labelled cellophane bags (Bamgbose *et al.*, 2000), and were taken to the laboratory for pre-treatment and analysis. Also a total of eighteen (18) fresh plant leave samples (Cynodon dactylon commonly known as Bahama grass, belonging to the family of Poaceae) three each were randomly collected from the vicinity of the sampling areas where the soil samples were collected. These samples were collected using a clean stainless steel pair of scissors (Okonkwo and Maribe, 2004), place in paper bags, labelled and taken to the laboratory for pre-treatment and analysis.

Sample preparation

Soil samples from each site were homogenized and air dried, crushed and ground then was sieved through 0.2mm sieve (Abdulmajeed 2013). Plant samples was rinsed with distilled water to remove any attached soil particles, the plant samples was cut in to smaller portions before placing in a large clean crucible where they are oven dried at 100^0C for 48h.The dried plant samples was grinded into fine particles using clean acid washed mortar and pestle (Awofolo 2005)

Sample Digestion

Two gram of soil sample was placed in $100cm^3$ tall form beaker. The digestions of the samples were done using aqua regia that is 3:1 ratio of hydrochloric acid to trioxonitrate (V) acid added to it and boiled gently on a hot plate until the volume was reduced to near dryness and then cool. $10cm^3$

of distilled water was added to it and then boiled gently again until the volume was approximately 2cm^3. The suspension was allowed to cool and filtered throw a Whatman No. 540 filter paper, the beaker and filter paper was washed with small portions of distilled water until a volume of about 25cm^3 was obtain. The filtrate was transferred into a 50cm^3 graduated flasks and made up to the mark with distilled water (Shinggu *et al*., 2010). The quantitation of metallic content of the soil samples was carried out in triplicates by atomic absorption spectrophotometer (AAS) 210 VGP Buck Scientific model following the procedure adopted by Barkbes *et al*., (2014). Two gram of the powdered plant sample was weighed into "high form" porcelain crucible, the crucible with the sample was placed into furnace and the temperature was increased gradually until the temperature reached 550^{0}C. The sample was ash until a white or grey ash was observed in the crucible. The ash was dissolved by adding 1mL of conc. HNO_3 to the crucible. The dissolved ash was transferred into 50mL volumetric flasks. It was diluted to volume with distilled water (AOAC, 2000). The quantitation of metallic content of the vegetation samples was carried out in triplicates by atomic absorption spectrophotometer (AAS) 210 VGP Buck Scientific model following the procedure adopted by Barkbes *et al*., (2014).

The ability of plants to uptake trace metals from the soil was determined using the transfer factor model (Olowoyo 2013). The transfer factor is calculated as the concentration of heavy metals in plant parts to the concentration present in the soil. This is an index of soil-plant transfer. Values >1 indicate that plants are enriched in elements from soil (accumulator), ratios around 1 indicate that plants are not influenced by elements (indicator), and values <1 show that plants exclude the element from soil (excluder).

Data Analysis

The data obtained for the Heavy metals were all subjected to analysis of variance and the result presented in mean and standard deviation. Pearson correlation was used to determine if there was a common source and relationship between the Heavy metals in roadside soil and plant.

Results

The results of the concentration of heavy metal in roadside soil sample for the study area were presented in Table 1, while Table 2 contains the result of the concentration of heavy metal in plant samples. The result of the analysis of variance did not show significant difference in concentration of the heavy metal among the sample areas at $p < 0.05$ level for both soil and plant samples.

Table 1: Concentration of Heavy Metal in Soil in the Study Area (mg/kg)

Sample location	Metal				
	Zn	Cr	Mn	Ni	Cu
Mubi	10.22 ±2.01	0.02±0.01	12.00 ±2.23	0.09±0.03	0.21±0.06
Mararaba	11.24 ±2.31	0.03 ±0.01	12.30 ±2.31	0.06±0.02	0.11±0.04
Makera	11.22±2.15	ND	11.92 ±2.81	0.04± 0.01	0.09±0.03
Kala'a	9.19 ± 1.31	ND	13.52±3.32	0.05 ±0.01	0.19±0.05
Hong	12.36± 3.00	0.01±0.00	11.02±2.51	0.12 ± 0.04	0.26±0.08
Gombi	13.40 ± 3.01	0.02±0.01	12.45±2.35	0.06±0.02	0.07±0.02
Range	9.19±1.31 – 13.40±3.01	0.01±0.00 – 0.03 ±0.01	11.02 ±2.51 – 13.52±3.32	0.04±0.01- 0.12±0.04	0.07±0.02 - 0.26±0.08
WHO	0 – 15	0 – 0.4	0 – 0.5	0 – 0.03	0 – 0.8

All values represent mean ± standard deviation of triplicate determination
Key: ND not detected

Table 2: Concentration of Heavy Metal in Plant in the Study Area (mg/kg)

Sample Location	Heavy Metal				
	Zn	Cr	Mn	Ni	Cu
Mubi	7.10±1.21	0.01±0.00	12.81 ± 2.53	0.09 ± 0.02	0.14±0.05
Mararaba	9.20 ± 1.89	0.01±0.00	11.92± 2.08	0.03± 0.01	0.06±0.02
Makera	10.16±2.22	ND	10.90±2.00	0.01±0.00	0.03±0.01
Kala'a	8.18±1.75	ND	11.55±1.95	0.01± 0.00	0.11±0.04
Hong	10.21±2.41	ND	9.43±1.82	0.06±0.02	0.19±0.07
Gombi	11.28±2.81	0.02±0.00	11.95 ± 2.11	0.02 ±0.00	0.04±0.01
Range	7.10±1.21-	0.01±0.00 -	9.43±1.82 -	0.01±0.00 -	0.03±0.01 -
	11.28±2.81	0.02±0.00	12.81±2.53	0.09±0.02	0.19±0.07
WHO	0 – 13	0 – 0.2	0 – 0.3	0 – 0.2	0 – 0.7

All values represent mean ± standard deviation of triplicate determination
Key: ND not detected

The result of the transfer factor for the study area was shown in Table 3; while Figure 1 shows the variation of transfer factor for each metal with sample area.

Table 3: Transfer factor of heavy metals in the study area

Heavy Metal	Sampling site				
	Mubi	Mararaba	Makera	Kala'a	Hong	Gombi
Zn	0.61	0.82	0.91	0.89	0.83	0.84
Cr	0.50	0.67	ND	ND	ND	0.50
Mn	1.07	0.97	0.91	0.85	0.86	0.96
Ni	1.00	0.50	0.25	0.50	0.75	0.33
Cu	0.67	0.55	0.33	0.58	0.73	0.56

Key: ND not detected

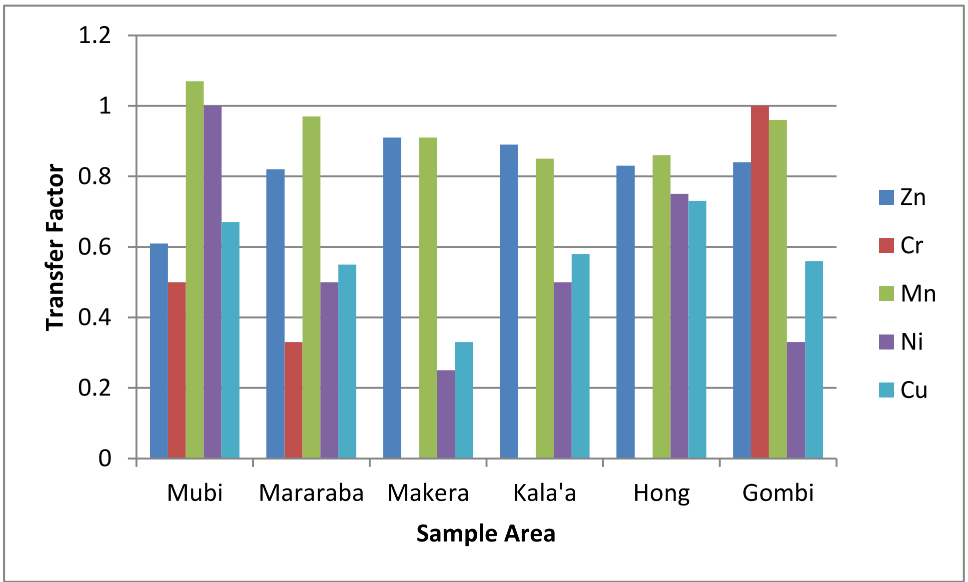

Figure 1: Variation of transfer factor for each Metal with Sample area

Table 4: Computed Pearson correlation coefficient between heavy metal levels between soil and plant samples in the investigated area

Correlations between Metals	r values
Correlation between soil and plant for Zn	r = 0.961**
Correlation between soil and plant for Cr	r = 0.944**
Correlation between soil and plant for Mn	r = 0.949**
Correlation between soil and plant for Ni	r = 0.989**
Correlation between soil and plant for Cu	r = 0.992**

** indicate significant at $p < 0.01$ level

Discussion

The concentration of Zn ranged from 9.19 ± 1.31 – 13.40 ± 3.01 mg/kg in soil Table 1 and 7.10 ± 1.21 – 11.28 ± 2.81 mg/kg in plant Table 2. The highest values 13.40 ± 3.01 mg/kg and 11.28 ± 2.81 mg/kg for soil and plant respectively were both observed in Gombi. While the lowest values 9.19±1.31 mg/kg and 7.10 ± 1.21 mg/kg were recorded in Kala'a and Mubi for soil and plant respectively. The observed values for soil and plant fall within the permissible limit of WHO. The result obtained in this study was lower than (31.5 – 123mg/kg) the one reported by Mafuyai *et al*., (2015) and 54.00mg/kg by Anthony and Balwanty (2005) for soil. However the value obtained in this study were higher than the value (5.93mg/kg) for plant reported by Tsafe *et al*., (2012). The presence of this amount of Zn in the sample may be accounted by the fact that Zn compounds are used extensively as anti-oxidants and as detergent /depressants improving agents for motor oil. Vehicle brake lining and tire wear have been identified as possible source of Zn (Zhang *et al.,* 2017).

The values of Cr ranged from 0.01 ± 0.00 – 0.03 ± 0.01 mg/kg and 0.01 ± 0.00 – 0.02 ± 0.00 mg/kg for soil and plant respectively Tables 1 and 2. The highest value 0.03±0.01 mg/kg and 0.02 ± 0.00mg/kg in soil and plant samples were recorded in Mararaba and Gombi respectively. The lowest value 0.01 mg/kg in soil was found in Hong and that of plant was observed in both Mubi and Mararaba. When compared with WHO standard limit all the values fall within the limit. The obtained values were lower than the values (1.13 – 2.79 mg/kg) reported by Mafuyai *et al*. (2015) for soil and that of Tsafe *et al*., (2012) 22.58mg/kg for plant. Cr is one of those heavy metals whose concentration steadily increases due to industrial growth especial the development of chemical and tanning industries. Other source of Cr in roadside dust is believed to be due to corrosion of vehicular parts (Li *et al*., 2001). Chromium and its compounds are known to cause cancer of the lungs, nasal cavity and para nasal sinus and suspected to cause cancer of the stomach and larynx (Shinggu, 2014).

The values of Mn ranged from 11.02 ± 2.51 – 13.52 ± 3.32 mg/Kg and 9.43 ± 1,82 – 12.81 ± 2.53 mg/kg for soil and plant respectively Tables 1 and 2. The highest value13.52 mg/Kg in soil was found at Kala'a. While that of plant were found at Mubi. The lowest value 11.02 ± 2.51 mg/Kg for soil and 9.43 ± 1.82 mg/kg for plant were both observed at Hong. The result of the investigation revealed that the values of Mn in the studied area were higher than WHO standard limit Tables 1 and 2. The result collaborate the report (8.44 mg/Kg) of Tsafe *et al*., (2012) for plant. The observed high value could be due to anthropogenic activity. Mn is essential nutrients that are required for biochemical and physiological function (Pual *et al.,* 2012).

The concentration of Ni ranged from 0.04 ± 0.01 – 0.12 ± 0.04 mg/kg and 0.01 ± 0.00 – 0.09 ± 0.02 mg/kg for soil and plant respectively Tables 1 and 2. The highest value (0.12 ± 0. 04 mg/kg) for soil was obtained at Hong, while that of plant 0.09 ± 0.02 mg/kg were recorded in Mubi. The lowest value 0.04 ± 0.01mg/kg for soil was recorded in Makera and 0.01±0.00 mg/kg for plant were recorded in Makera as well as Kala'a. When compared with WHO standard limit all the values in soil sample were above. However, in plant the values at Makera and Kala'a were below. The result collaborate the report (0.88mg/kg) of Mafuyai *et al.,* 2015.

The sources of Ni in roadside soil are believed to be due to corrosion of vehicular parts. The rate of high corrosion and wear from old vehicle (as a result of high patronage in imported used cars) playing the road could have accounted to the significant levels of anthropogenic contribution of Ni in roadside soil (Mafuyai *et al.*, 2015). Also Nickel can be found naturally in the atmosphere as a result of wind-blown dust, derived from the weathering of rocks and soils, volcanic emissions, forest fires and vegetation, the combustion of coal, diesel oil and fuel oil, the incineration of waste and sewage, and miscellaneous sources such as tobacco smoking, stainless steel kitchen utensils, inexpensive jewelry etc. The absorption of nickel is dependent on its physicochemical form, with water-soluble forms (chloride, nitrate, sulphate) being more readily absorbed (Adah *et al*., 2013). Ni present in fuel as anti-knock agent and is a toxic metal (Suzuki and Ono 2008).

The concentration of Cu ranged from 0.07 ± 0.02 – 0.26 ± 0.08 mg/kg and 0.03 ± 0.01 – 0.19 ± 0.07 mg/kg for soil and plant respectively Tables 1 and 2. The highest values 0.26 ± 0.08 mg/kg and 0.19 ± 0.07 mg/kg for soil and plant were both found at Hong. While lowest values 0.07 ± 0.02 mg/kg and 0.03 ± 0.01 mg/kg were found at Gombi and Makera for soil and plant respectively. The obtained values were within WHO standard limit for both soil and plant. When compared with the report 1.13mg/kg for soil and 26.33 mg/kg for plant by Tsafe *et al*., (2012), the values in this study found to be lower. The presence of Cu in road side soil is attributed to smelting, battery and soldering work. Cu is also derived from engine wear, thrust bearings, bushing and bearing metals (Akbar *et al.*, 2006).

The transfer factor (TF) showed that some of the plants did take up most of the metals directly from the soil. From the results, the highest transfer factor recorded was in Mn at Mubi with the value of 1.07, followed by Ni at Mubi with value of 1.00. The TF showed that the concentration of Mn were greater than 1, which shows that plants were enriched by Mn from the soil. Ni and Cr equal to 1 at Mubi and Gombi respectively. All the values of TF at the study area super pass 0.5 this implies that generally the bioaccumulation of heavy metals in plants was high this could be attributed to the low retention rate of the metal in soil and therefore it is more mobile in the soil with the exception of Mubi for Cr, Mararaba for Ni, Makera for Cr, Ni and Cu , Kala'a for Cr and Ni, Hong for Cr and Gombi for Cr. The findings in this study collaborate with the report of Tsafe *et al.,* (2012). The transfer factor for Cr was 0.5 at Mubi indicating that the soils from these places were contaminated with this metal. However for the other sample areas, Cr was not detected.

Zn and Cu showed a considerable high Tf value with all values surpassing 0.5 at all the sample areas with the exception of Cu at Makera Table 3 indicating that plants were largely contaminated with Zn and Cu from anthropogenic sources, and this is based on the suggestion that the greater the transfer coefficient value than 0.50, the greater the chances of plant for metal contamination by anthropogenic activities (Mohammed and Folorunsho,2015).

Plant roots are the most important site for uptake chemicals from soil (Addo 2012). In an attempt to understand this relationship, the Pearson Correlation Coefficient, r, was used to establish the relationship between the concentrations of corresponding metals evaluated from the soil and plant samples. As shown in Table 4, the correlation coefficients (r) between the mean concentration of heavy metal in the roadside soil and plant (Table 4) showed strong positive correlation for all the metals studied. This suggests a strong relationship between the soil metal levels and the plant metal contents. The results of positive correlation between soil and plants have been supported by earlier findings (Addo et al 2012; Mohammed and Folorunsho, 2015). Thus, indicating that plants take nutritional elements from soil through their roots.

Conclusion

Generally the result of the study revealed that the concentration of heavy metals decreased as the distance away from the edge of the road increased. The concentrations are in the order Mn>Zn>Cu>Ni>Cr for both soil and plant samples. There was no significant difference in concentration of the heavy metal among the sample areas at $p < 0.05$ level for both soil and plant samples. The transfer factor (TF) showed that some of the plants did take up most of the metals directly from the soil.

High positive correlation was observed between the concentrations of the metals in soil and plant samples at $P<0.01$, indicating that plants take nutritional elements from soil through their roots. It could also mean that roadside soil and plant contamination by metals originated from a common anthropogenic source, with probably automobiles as a major common source.

Consequently, it is imperative to continually assess and monitor the levels of heavy metals in roadside soil and plants due to anthropogenic activities for evaluation of human exposure and for sustainable environment.

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