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A comparative study on the pollution status of heavy metals in soils and sediment from farmlands in Askira Uba, Nigeria

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Abstract

Heavy metals may enter the food chain from soil through mineralization by crops or environmental contamination, as in application of agricultural inputs such as pesticides and fertilizers or in the treatment of soils with sewage sludge cupper content of normal plant tissue. Atomic Absorption Spectroscopic (AAS) method is one of the most commonly used instrument in metal analysis due to its reproducibility of results, short analysis time, lower level of detection. Soil and sediments samples were collected at three distinct stations each, designated as A1, B1, C1 and A2, B2, C2 respectively from Askir/Uba local government area of Borno State, Nigeria. The concentrations of six heavy metals of environmental concern which includes Cd, Cu, Cr, Pb, Ni and Zn were determined by Atomic Absorption Spectrophotometer; Buck scientific model 210GP. The mean concentration of Cd in soil and sediment were (10.7±2.32 mg/kg and 9.62±2.32 mg/kg) and are of toxicological concern. The decrease in concentrations of the metals across sampling locations followed this order Cd > Cu > Cr > Pb > Ni > Zn.

The geoaccumulation index of the sediment by each metals are in the following increasing order: B2 < A2 < C2 for Cd and Pb, B2 < C2 < A2 for Cr, A2 < B2 < C2 for Cu, A2 < B2 < C2 for Zn respectively. In general, the order of metal contamination were Zn < Ni < Cu < Pb < Cr < Cd.

The results of the findings revealed that the soil and sediment were contaminated with Cadmium, the high level of Cd in the soil were above the recommended values. However, Independent-samples t-test (statically significant at $p<0.05$) was used to compared the average metal composition in soil and sediment which showed that there was no significant difference on the composition in soil and sediment for all the metals p-value = 0.8939

The aim of the study was to compare the mean level of the soil and sediment with WHO permissible limit, hence evaluate their pollution status by the application of geoaccumulation index.

Keywords: Heavy Metals; Concentration; Geo-acumulation; Sediment; Soil

1. Introduction

Heavy metals are important group of pollutants, due to their non-biodegradable nature; they are not readily detoxified and removed by metabolic activities once they are available in the environment. Bioaccumulation of these heavy metals in plants, humans and other animals results in metal poisoning (Audu and Lawal, 2005). Metals may enter the food chain from soil through mineralization by crops or environmental contamination, as in application of agricultural inputs such as pesticides and fertilizers or in the treatment of soils with sewage sludge cupper content of normal plant tissue. Anthropogenic activities such as; transportation, burning of fossil fuel, construction and manufacturing increase the

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concentrations of heavy metals in the soils and in some plants (Adesuyi *et al*., 2015; Adesuyi *et al*., 2016). Other sources of anthropogenic contamination include the addition of manures, sewage sludge, fertilizers and pesticides to soils, with a number of studies identifying the risks in relation to increased soil metal concentration and consequent crop uptake (Kachenko and Singh, 2006). Some heavy metals are bio-accumulative in nature in various plant parts, resulting in poor growth of plants (Girisha and Ragavendra, 2006) and pose great danger to the various elements of the food chain in any given environment. Sediments are known to be "Trace element traps" (Eugenia, 2004) because they eventually bind almost all the contaminants which enter the aquatic environment (Karthikeyan R, 2007). Heavy metals in sediments can lead to greater environmental problems when the contaminated sediments are re-suspended and such metals are taken-up by filter feeders. Sediments can reflect the quality of the water system and can be used to detect insoluble contaminants (Karthikeyan, 2007).Heavy metals can be found in amounts several times above their natural background limits and pollute sediments and water next to industries, urban areas, and mining activities. (Andrade *et al*., 2001; Masoud *et al*., 2005)

The assessment of sediments developed recently into a foremost issue of significance that can reveal the existing quality of the environment as well as provide vital information on the anthropogenic activities within the aquatic biota. Sediment can be defined as loose sand, clay, silt and other soil particles that settle at the bottom of water body. Corrosion of bedrock and soils leads to accumulation of sediment of current natural and anthropogenic activities as well as their component (Davies and Abowei, 2009). The major contributing factor to metal contamination in the sediment are through numerous pathway such as industrial disposal of liquid effluents, surface runoff, domestic discharge and leachates carrying chemicals originating from numerous urban and agricultural activities as well as atmospheric deposition (Adefemi *et al.,* 2008).

2. Material and methods

2.1. Description of the Study Area

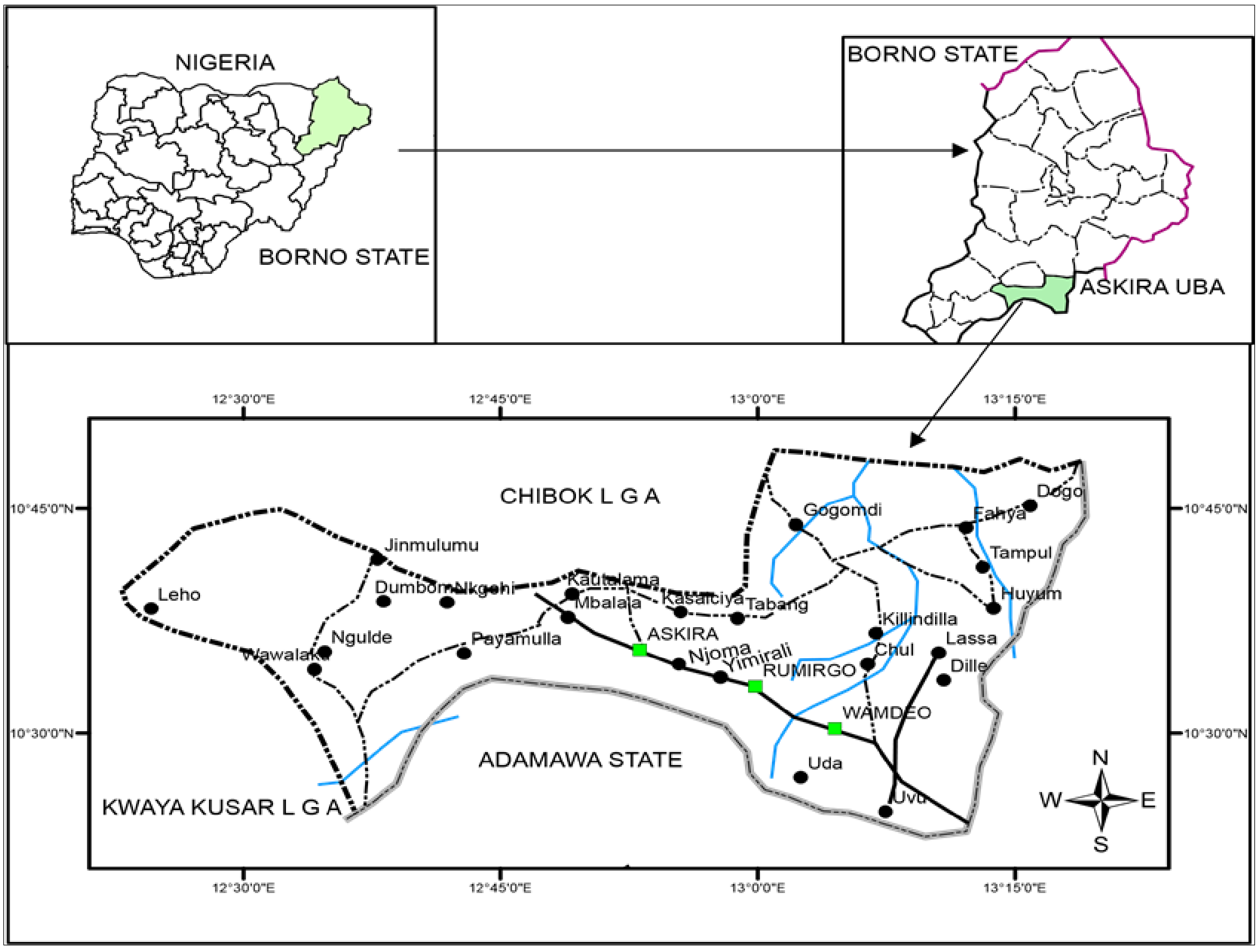

Figure 1 Map of Borno State Showing Askira Uba Sample Location

Askira/uba is the one of the biggest local government area in the south of Borno state, with its headquarter located in Askira town. It has two Chiefdoms, one in Askira and the other in Uba. It has an area of 2,362km^2 and a population of 138,091 as at 2006 census. It is geographically located at longitude $12^{0}22^{1}3^{11}$ to $13^{0}19^{1}48^{11}$E and latitude $10^{0}22^{1}34^{11}$ to $10^{0}49^{1}43^{11}$N.

The major tribes in Askira/uba local government are Margi, Chibok and Fulani. The main occupation of the people of Askira/Uba are mostly farming and cattle rearing. The people of Askira/ Uba produced lots of food and cash crops such as groundnut, Maize, Rice, Millet, Beans, Soya beans, Sorghum, Bambara-nut, Beni-seed and Vegetables such as Okro, Karkashi and Yakuwa (Rosel) and many others which they sold to other neighboring local government as well as other states. The raining season begins around April and last till late October.

2.2. Sample Collection, Preparation and Metal Determination

Samples were collected from the month of September, 2022. Soil samples were collected from Askira/uba local government area of Borno State and were labelled A1, B1, C1 for Askira, Wamdeo and Rumirgo respectively. In each plot, soil samples were collected at two depths (0-15 cm and 16-30 cm), using spiral auger of 2.5 cm diameter or ruler. The Soil sample was randomly selected and bulked together to form a composite sample before being placed in clean plastic bags and transported to laboratory. Sediment samples were also collected from same area using a plastic hand trowel by scooping 1-5 cm of the top layer sediment. Fifty gram (50 g) of sediment sample were collected at each point and labeled A2, B2, C2 for Askira, Wamdeo and Rumirgo respectively. The samples were wrapped in a labeled aluminium foil paper, the labeled sample were stored in an ice-packed cooler and transported to the laboratory and stored in a refrigerator at 4 °C for further analysis.

The soil and sediment samples were digested by weighing 1.0 g each into different pyrex beakers. 15 mL of HNO_3 followed by 10 mL of HCl and 5 mL HF were added to the samples. The samples were heated at 180 °C on hot plate for 1 hour until all brown fumes escaped leaving the digested sample. The samples were allowed to cooled and diluted with deionized water, samples were filtered and the filtrate were made up to 50 mL with deionized water. (Qin *et al*., 2014). The concentration of the metal ions present in the sample were determined by reading their absorbance using Atomic Absorption Spectroscopy (Buck scientific model 210GP). Triplicate analysis were made.

3. Results and discussion

3.1. Mean Concentrations of Heavy Metals in Soil and Sediment (mg/kg) from Askira/Uba LGA (Askira A1, A2 Rumirgo B1, B2 and Wamdeo C1, C2)

The mean concentrations of heavy metals in soil from Askira/Uba LGA (Askira, Rumirgo and Wamdeo) are presented in Table 1. The results also showed that all the metals do not follow the same trend of occurrence in the three farmlands; that is, each metal concentration varies independently from one another according to their sources.

- **Cadmium (Cd):** The concentration of Cd in all the three soil samples were A1 (10.89 mg/kg), B1 (7.78 mg/kg) and C1 (13.46 mg/kg) with mean values of 10.7±2.32 mg/kg. Whereas the concentration of Cd in sediment samples from the three locations varied from 7.59 – 12.07 mg/kg with mean value of 9.62±2.32 mg/kg. Cd recorded the least concentration among the studied metals in both soil and sediment samples. This is due to it geological occurrence and minimal occupational activities in the area. The values of Cd obtained were above the World Health Organization permissible limit (0.80 mg/kg) for soil and sediment (WHO/FAO, 2001). Cd can accumulate and biomagnified in the soil which could leads to alteration of the food chain. Although Cd is the least of the heavy metals found on the three farmlands, its concentration is still far above the background level (0.2 - 1.0 mg/kg) according to the United States Environmental Protection Agency (Kubire *et al*, 2019).
  Cadmium is ranked as the 7th among the top 20 toxic metals (Sun *et al.,* 2019) and is a severe threat to our environment due to its rising accumulation in agricultural soils through various components of irrigation, both indoor and outdoor (Anjum *et al.,* 2016). In plants, Cd phytotoxicity results from Cd-induced oxidative stress. Oxidative stress impairs lipids, nucleic acids, and proteins, which in turn inhibits growth in the plant and can even cause cell death (Loix *et al.,* 2017). In living organisms, cadmium occupies higher toxicity and mobility as compared to other harmful heavy metals (Li *et al.,* 2017). Since the Cd content of Askira, Rumirgo and Wamdeo is well above the permissible limit, it is certain that plants grown on those farmlands will suffer from the effects mentioned. Although the effects are both plant species-dependent and does-dependent, some plants show Cd tolerance through a wide range of cellular responses.
- **Chromium (Cr):** The concentration of chromium Cr ranged from 37.0 mg/kg at A1 to 95.80 mg/kg at C1 with a mean concentration of 75.4±27.2 mg/kg. However, the concentration of sediment in locations A2 – C2 varies

from 77.28 - 94.93 mg/kg with mean of 86.4±7.22 mg/kg. The mean of concentration of Cr in both soil and sediment samples reported in this work is greater than the mean value (11.55 mg/kg) reported by Benedicta et al., (2017). The high concentration of Cr recorded at C1 could be as a result of burning of e-waste such as used computers, cables and automobile tires at the occupational areas close to the farmlands.

- **Copper (Cu):** The concentration of Cu ranged from 38.42 to 43.29 mg/kg across A1 to C1 respectively with the least concentration of 38.42 mg/kg in A1 while the highest concentrations were found in B1 (42.87 mg/kg) and C1 (43.29 mg/kg) with mean values of 41.5±2.20 mg/kg. On the other hand, the highest concentration of Cu in sediment samples was observed at sample location C2 (58.68 mg/kg) followed by B2 (51.19 mg/kg) with the least at A2 (43.45 mg/kg). The threshold level of Cu in soil and sediment according to WHO/FAO (2001) is 36.0 mg/kg.

Table 1 Mean Concentrations of Heavy Metals in Soil and Sediment (mg/kg) from Askira/Uba LGA (Askira A1, A2 Rumirgo B1, B2 and Wamdeo C1, C2)

Locations/ Metals	**Cd**	**Cr**	**Cu**	**Pb**	**Ni**	**Zn**
A1	10.89	37.00	38.42	57.29	20.69	24.16
B1	7.78	93.36	42.87	46.23	20.69	30.12
C1	13.46	95.80	43.29	64.57	23.95	28.40
Mean Values	10.7±2.32	75.4±27.2	41.5±2.20	56.0±7.54	17.4±6.97	27.6±2.51
A2	8.40	94.93	43.45	46.67	25.86	31.18
B2	7.59	77.28	51.19	42.96	32.53	39.51
C2	12.07	86.89	58.68	64.69	36.47	43.66
Mean Values	9.62±2.32	86.4±7.22	51.1±6.22	51.4±9.49	31.6±4.38	38.1±5.19
WHO (2001)	0.800	100	36.00	85.00	50.00	300.0

This result is similar to the findings of Zhang *et al.,* (2012) which recorded extremely high concentrations of copper at e-waste sites, which was beyond the acceptable agricultural soils limits of 50 mg/kg in China. Excess Cu is known to impart negative effects on plant growth and productivity. Such effects are in terms of germination, growth, photosynthesis, and antioxidant response in agricultural crops. Its inhibitory influence on mineral nutrition, chlorophyll biosynthesis, and antioxidant enzyme activity has been verified. However, farmlands with Cu concentration lower than the standard background level are not expected to have such effects on crops.

- **Lead (Pb):** The concentrations of Pb in presented in Table 1 were in ascending order of B1<A1<C1 corresponding to 46.23, 57.29 and 64.57 mg/kg with mean concentrations of 56.0±7.54 mg/kg while the mean concentrations of Pb in sediment samples ranged from 42.96 – 64.69 mg/kg across A2 – C2 respectively. Compared mean concentrations of Pb obtained in this study to WHO/FAO standard, the amount of Pb in soil and sediment from the three farmlands (A1, A2; B1,B2 and C1,C2) were below the world health organization (WHO/FAO, 2001) permissible limit for Pb in soil (85.0 mg/kg) as reported by Marilda *et al,* (2015). Hence impacts resulting from Pb cannot be felt on consumers of crops grown on any of the three locations.
- **Nickel (Ni):** The mean concentrations of nickel recorded in the soil samples were A1 (20.69 mg/kg), B1 (7.80 mg/kg) and C1 (23.95 mg/kg) with a mean value of 17.4±6.97 mg/kg while those of sediment were 25.86, 32.53 and 36.47 mg/kg for A2, B2 and C2 respectively. The mean concentration of Ni in soil and sediment recorded at the various locations were below the WHO/FAO (2001) permissible limit of 50 mg/kg for soils and sediment. However, the concentrations of Ni in sediments were greater than those of the soil.
- **Zinc (Zn):** The mean concentration of zinc (Zn) ranged from 24.16 mg/kg at A1 to 30.12 mg/kg at B1 with a mean value of 27.6±2.50 mg/kg. The maximum concentration of Zn in soil was recorded at B1 (30.12 mg/kg) and sediment at C2 (43.66 mg/kg). The concentrations of Zinc in both soil and sediment samples studied in this work were below the WHO/FAO (2001) allowable limit of 300.00 mg/kg for soils and sediments. The presence of zinc in soil at the various locations may be as a result of the occurrence of battery dry cells from run-off water as reported by Thorpe and Harrison (2008). Li *et al.,* (2011) reported a mean value of 3,500 mg/kg for Zn which were 100 times greater than those reported in this findings. Zinc is a vital microelement which plays a very

important catalytic role in enzyme reactions (Knezevic *et al.,* 2009). The concentrations of Zn in both soil and sediment were below the recommended values by WHO (2001).

3.2. Geo-accumulation Index (Igeo) for Heavy Metals in Soil and Sediment from Askira/Uba LGA (Askira, Rumirgo and Wamdeo)

The Igeo values for the three different soil samples were range from 1.560 - 2.700 for Cd indicating that the soil were moderately contaminated with Cd while Cr, Cu, Pb, Ni and Zn had values less than 1 which indicates non-contamination. In general, the order of metal contamination were Zn < Ni < Cu < Pb < Cr < Cd. Related work was carried out by Safiur *et al.* (2022). It shows that only Cr and Fe have the Igeo values of 2 and 4 while the rest of the metals indicated Igeo values below zero.

Table 2 Geo-accumulation Index of Heavy Metals in Soil (A_1 – C_1) and Sediment (A_2 – C_2)

Metal	A1	B1	C1	A2	B2	C2
Cd	2.190	1.560	2.700	1.686	1.523	2.422
Cr	0.080	0.210	0.210	0.212	0.172	0.194
Cu	0.150	0.170	0.170	0.174	0.205	0.236
Pb	0.160	0.130	0.190	0.134	0.123	0.185
Ni	0.060	0.020	0.070	0.076	0.096	0.108
Zn	0.030	0.040	0.030	0.036	0.045	0.050

The Igeo values in sediments showed almost a similar trend of variation to those of soil. Zn has the least Igeo values, ranging from 0.040 – 0.050, indicating contaminated to moderately contaminated sediment. The highest geo-accumulation index value was recorded in Cd which ranged from 1.520 – 2.420. This falls on class 3 (moderately to heavily contaminated). However, the contamination of the sediment site by each metal is in the following increasing order: B2 < A2 < C2 for Cd and Pb, B2 < C2 < A2 for Cr, A2 < B2 < C2 for Cu, A2 < B2 < C2 for Zn respectively.

4. Conclusion

The results of the findings revealed that the soil and sediment were contaminated with Cadmium, the high level of Cd in the soil were above the recommended values. However, Independent-samples t-test (statically significant at $p<0.05$) was used to compared the average metal composition in soil and sediment which showed that there was no significant difference on the composition in soil and sediment for all the metals p-value = 0.8939.

Compliance with ethical standards

Acknowledgement

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Disclosure of conflict of interest

The authors declare no conflict of interest.

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