Assessment of Geo-Accumulation indices of Some Selected Heavy Metals Using AAS in Langtang North, Nigeria

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Abstract: - Samples of soil sediments of Bala, Gantang, Shi–for, Walang, Yangang Streets and Intorok street (control), Langtang North, Plateau State, Nigeria, were assayed using Atomic Absorption Spectrophotometry for selected heavy metals (As, Pb, Cd, Co, Cr, Cu, Fe, Mn, Ni and Zn). The results found in this study show that the Geo-accumulation index assessment ranged between 0.00 – 2.58 with Bala street having the least value, while Gantang street has the highest value this implies un-contamination to strongly contaminated. Contamination indices of the sediment samples indicated that Cr, Zn, As, and Pb were the greatest contaminants. It is therefore recommended that further research should be carried out to determine the concentrations of other heavy metals in the study area with different streets samples to ascertain the geo-accumulation index. Green plants should be used to remove environmental contaminants like heavy metals from soil especially in Bala Street which already has about 2.58 index. Area with low contamination like Bala and Intorok should also maintain status quo of good environmental preservation. Lastly, human activities such as agricultural activities should not be close to streets to prevent excessive buildup of heavy metals in plants or soil.

Key Words:— *Geo-Accumulation, Heavy Metals, AAS, Environmental Preservation.*

I. INTRODUCTION

Most of the developing countries are facing the severe environmental issue of soil pollution by heavy metals due to increased industrialization and urbanization. The problem is ranked among the most significant environmental challenges worldwide which requires evaluation and urgent solution to overcoming the negative impacts (Kutty and Al – Mahageri, 2016; Mafuyai *et al*., 2019). Soil is a heterogeneous mixture of organic and inorganic substances in which the binding mechanism of metals varies with the composition of the soil. Accumulation of heavy metals in soils is of great concern due to the probability of food contamination through soil root interface. Soil, water and atmosphere represent a growing environmental problem affecting food quality and human health, (Mafuyai *et al*., 2020). Though heavy metals cadmium, chromium, cobalt and lead are not essential elements, they are readily taken up accumulated in plants in toxic forms. The ecological effects of heavy metals in soil are closely related to the distribution of species in the solid and liquid phase of the soil. The presence of heavy metals in soil is of great ecological significance owing to their toxicity at certain concentrations. (Opaluwa *et al.*, 2012). Heavy metal pollution in soil has become serious with rapid industrialization and urbanization over the first two decades, (Teng, 2014; Li *et al.*, 2015). The toxic heavy metals entering the ecosystem may lead to geo – accumulation and bio – accumulation, (Henry *et al*., 2018).

Pollution is the cause of many diseases, which affect not only the old, but also the young and energetic as well as all animals and plants (Kanmony, 2009). Surface soil may act as carriers and possible sources of pollution, since the mobility of these metals is such that they remain in the upper layers without regard to type of soil. The metals are not permanently fixed and can therefore be released by changes in climatic or environmental conditions such as rainfall and soil pH (Ajibola and Ozigis, 2005). WHO report pointed out that twenty million children worldwide suffer from pollution which has become critical because of over-population (Pain, 2008). The presence of heavy metals at trace level and essential elements at elevated concentration causes toxic effects if exposed to human

Manuscript revised August 04, 2021; accepted August 05, 2021. Date of publication August 06, 2021.
This paper available online at www.ijprse.com
ISSN (Online): 2582-7898

population (Fong *et al*., 2008). The most important source of heavy metals in the environment are the anthropogenic activities such as road construction, mining, smelting procedures, steel and iron industries, chemical industries, traffic, agriculture as well as domestic activities, (Ruqia *et al*., 2015). These heavy metals may adversely affect soil ecology, agricultural product quality and ground water quality and will ultimately harm the biota. This effects are closely related to the biological availability of heavy metals which in turn are controlled by the metal ion speciation in the soil therefore, the determination of free metal ion concentration in soil solution becomes important, the free metal ion concentration not only depends on the total metal content in the soil, but also on the metal species that exist in soil, (Ene *et al*., 2009).

A. Heavy metals and environmental pollution

The presence of different types of toxic heavy metals in high concentrations in the environment is called heavy metal pollution (Bose and Hemantaranjan, 2005). Heavy metals refer to elements with a density greater than 5.00 g/cm3 in the form of elements (Bose and Hemantaranjan, 2005; Misra and Mani, 2009). Heavy metal pollution has received attention from researchers around the world, mainly due to its harmful effects on organisms (Misra and Mani, 2009).

The presence of heavy metal toxicity in soil has led to mass deaths in many countries in the world (Shrivastav, 2001). All heavy metals are toxic to organisms when the concentration is too high, although some heavy metals are essential to the normal and healthy growth and production of plants at low and critical concentrations. (Bose and Hemantaranjan, 2005). Traces of essential heavy metals required for plant production include: cobalt, copper, iron, molybdenum, and zinc, while animals are chromium, nickel, and tin. Heavy metals such as cadmium, lead, and mercury have not been shown to be necessary for plants or animals (Misra and Mani, 2009).

The concentration of individual metals and living tissues must be kept at a very low level and must be kept within a narrow range to ensure the best biological performance of most organisms (Misra and Mani, 2009). Heavy metals are not biodegradable and once they enter the environment, they will remain there for a long time (Voet et al., 2008). Heavy metals are considered serious pollutants due to their toxicity, persistence and non-biodegradability in the environment. Therefore, they pose a threat to human and other forms of biological life (Adeleken and Abegunde, 2011). Heavy metals exist in the atmosphere in the form of particles. Therefore, particles in the air are transferred to land or water through dry, humid and hidden locations, constituting the first stage of atmospheric heavy metals (Mafuyai et al., 2019); Adeleken and Abegunde (2011) observed the environmental mobility of heavy metals Lower. Therefore, a pollution may lay the foundation for long-term exposure of humans, microorganisms, fauna, flora and other soil communities to heavy metals. The heavy metal air pollution problem will not disappear overnight. On the contrary, it will remain the legacy of many generations of large-scale industrial activities and may increase further in the future (Shrivastav, 2001).

II. Evaluation Of Heavy Metals In Road Soils

The ecological risk assessment of some heavy metals in roadside soils at Traffic Circles in Gombe, Northern Nigeria was reported by Sulaiman *et al.* (2018). This 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 metals (Pb, Cd, Cu and Zn) using Atomic Absorption Spectrophotometry. The 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 (Igeo) 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 indicated that the metals posed low ecological risk and cadmium contributed 66.63 - 94.21 % of the total potentially ecological risk.

III. Material And Method

A. Study Area

This study was carried out in Langtang North Local Government Area of Plateau State, Nigeria. (Figure1). The study area is located at 9º08’00”N 9º47’00”E/9.13333ºN 9.78333ºE. It has an area of 1,188 km^2 and a population of 140,643 based on 2006 Census (Wikipedia, 2019).

The inhabitants are synonymous with farming and commerce. It is the administrative capital and the commercial nerve center of the LGA and is the most densely populated area in the Local Government according to the 2006 Nigerian census result. It has the highest number of aging automobile plying its roads compared to any part of the Local Government Area which contribute greatly to the source of heavy metals in the environment. Six sampling sites of Bala, Gantang, She – For, Walang, Yangang Streets and Intorok Street where selected, with Intorok Street used as control. At each sampling point, 500.00g of soil was collected over a depth 0-10 cm using a stainless-steel sampler. Soil samples along roads were collected at a distance of 1.00 m away from the road and within an area of 1.00 m^2. Three (3) samples were collected from each point, thoroughly mixed in a clean plastic container to obtain a representative sample, dried, crushed, sieved with a 2 mm mesh, kept in polyethylene bags and labeled prior to the analyses. The soil samples were labeled according to the regions from which they were obtained.

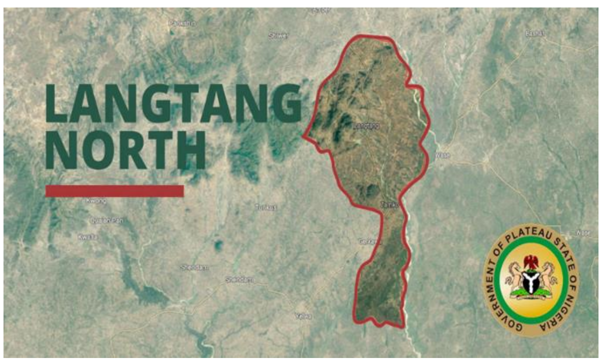

Fig.1. Map of Langthang North Local Government Area

(Source: Information Unit, Langtang Local Government Area)

B. Reagents

Reagents of analytical grade such as Sodium Ethanoate Solution, Hydroxylamine Hydrochloride, (v/v) Ethanoic Acid, Trioxonitrate (V) Acid (v/v) Hydrogen Peroxide, Aqua Regia, Ammonium Ethanoate Solution (v/v) Trioxonitrate (V) Acid, (v/v) Trioxonitrate (V) Acid and Oxalate Buffer.

C. Geo-accumulation Index (Igeo)

The degree of metal enrichment can be assessed using the Geo-accumulation Index (Igeo) adopted by (Adebayo *et al*., 2020). The Igeo calculation is based on the following equation:

$$I_{geo} = Iog2 \frac{C_n}{1.5B_n}$$

Where Cn is the measured concentration of metal in the sediment, Bn is the geochemical back ground concentration for the same elements (n) and factor 1.5 is the background matrix correction factor due to lithological variations. In this study, the background values of heavy metals Bn (As = 1,17, Cd = 0.67, Co = 1.17, Cr = 3.45, Cu = 7.33, Fe = 12.33, Pb = 4.67, Mn = 5.17, Ni = 7.00 and Zn = 6.33 mg/ kg).The Igeo includes seven grades: uncontaminated (Igeo < 0), uncontaminated to moderately contaminated (0 < Igeo < 1), moderately contaminated (1 <Igeo < 2), moderately to strongly contaminated (2 < Igeo < 3), strongly contaminated (3 <Igeo < 4), strongly to extremely contaminated (4 < Igeo < 5) and extremely contaminated (Igeo > 5).

IV. RESULT AND DISCUSSION

Performed a two-way analysis of variance to determine the levels of heavy metals in the six interchangeable bonding metal components, carbonates, manganese, iron/manganese, organics/sulfides, and residues. The analysis results show that there are significant differences between metal concentration levels based on fractionation, street, and metal type. The analysis results show that, at the metal concentration level, there are significant interactions between lanes and fractions, lanes and metal types, and fractions and metal types. The total metal concentration of soil sediments is roughly concentrated in exchangeable content, carbonate, reducible manganese oxide, iron oxide/manganese (reducible), organic/sulfide (oxidizable) and residual combined metal content. The concentration of arsenic in the soil of the five streets ranges from 0.00 to 37.00 mg/kg, which is lower than the soil target value (200.00 mg/kg) and the soil intervention value (625.00 mg/kg) (DPR, 2002). However, the control value obtained (7.00 mg / kg) is higher than the value obtained in bullet (0.00 mg / kg) and she-for (5.00 mg / kg). The arsenic in the soil in the study area comes from various man-made sources, including municipal and commercial waste, and the use of pesticides / herbicides. Arsenic in the environment is not immediately dangerous. The concentration of cadmium ranges from 4.00 mg / kg (found at Varang Street and Control Street) to 53.00 mg / kg (Yong Street). This is less than the 75.00 mg / kg determined by Nduka et al. (2014). The presence of cadmium may be the result of human activities. For example, the use of artificial phosphate fertilizers may increase the cadmium content in roadside soil samples in the study area. The cobalt concentration in the five lanes ranges from 0.00 mg/kg (Yangang lane) to 95.00 mg/kg (bullet lane). 95.00 mg/kg is consistent with the threshold limit of 100.00 mg/kg (Adagunodo et al., 2018). However, it is higher than the 7.00 mg/kg of the control test. Building materials and hospital waste can be used as a source of cobalt for these streets in the study area. Cobalt is also naturally present in rocks and soil. Cobalt is used as a desiccant for paints and tiles in the chemical industry, and the use of these products in the study area will also affect the cobalt content in roadside soil samples. The concentration of chromium detected in the five soils of this street is between 52.00 mg/kg (Gantang Street) and 211.00 mg/kg (Zibultou Street). These values are higher than the 21.00 mg/kg analyzed by the control lane (Intorok), and also higher than the chromium value (100.00 mg/kg) reported by Iwegbue et al. in 2013, and 150.00 micrograms/g (mg/kg). European Union standards (Sigh et al., 2010). However, the chromium concentration in the soil is as high as 350.00 mg / kg (Ertani., Et al 2017). Chromium has been found in at least 1,127 to 1,699 waste sites that have been proposed for inclusion on the EPA's National Priority List (NPL) (HazDat 2007). Most of the chromium in the study area is naturally present in rocks, soil, and garbage dumps. Chromium is an essential trace mineral and because a small amount of chromium is necessary for human health, it is used in the form of supplements to treat chromium deficiency, diabetes, and high cholesterol. Inhaling high concentrations of chromium will irritate the nose and throat, but pure chromium has no adverse effects on the human body. (Lenntech, 2019). The copper concentration in the soil samples of the five lanes analyzed ranged from 58.00 mg/kg (shefor) to 92.00 mg/kg (gantang). This is higher than 36.00 mg/kg (DPR, 2002) and lower than 100.00 mg/kg, the cumulative total of 44, 00 mg/kg found in FAO/WHO, 2001 and Intorok (control). Copper can exist in the soil through natural sources such as wind and dust and man-made sources (phosphate fertilizer production, wood production, and metal pollution such as vehicles and electrical appliances burned down this street, because copper is commonly found in cables). The manganese content measured in the five soils in this street ranged from 58.00 mg/kg (shefor street) to 144.00 mg/kg (yangang street). The observed value of the control is higher than 31.00 mg/kg, but lower than the 850.00 mg/kg soil established by DPR (2002) and the 2000.00 mg/kg soil limit established by FAO/WHO (2001). Manganese can exist in the form of solids in the soil, small particles in water, and dust particles in the air from fossil fuels. (Lenntech, 2019). The nickel content in the soil of the five streets ranges from 51.00 mg/kg (Walang) to 129.00 mg/kg (Gantang). The cumulative amount obtained by the control was 42.00 mg/kg. However, these values are lower than the soil intervention value (210 mg / kg) (DPR, 2002). A small amount of nickel is essential, but when the intake is too high it can pose a risk to human health, which can lead to respiratory failure, birth defects, heart disease and asthma. Atmospheric deposition is the main source of nickel in the soil of the study area. The lead concentration obtained in this study ranged from detection at Shefer Street (41.00 mg / kg) to 360.00 at Gantang Street. Intorok's measured value is 28.00 mg / kg. However, the reported lead concentration range (41.00 to 360.00 mg/kg) is within the maximum allowable level of 250 to 500 mg/kg in dry soil proposed by the FAO/WHO (2007). The high levels of lead observed may be related to lead particles from the combustion of gasoline, which were deposited on the street floor around the machine station. Domestic waste is one of the sources of lead emissions, surface drainage and atmospheric deposition in the study area. The concentration of zinc analyzed in the five lanes ranged from 54.00 mg/kg (shefor) to 254.00 mg/kg (gantang). This is higher than the 38.00 mg/kg found in the control lane and also higher than the allowable limit of 50.00 mg/kg (WHO, 2007). However, this is much lower than the zinc content (832.00 mg / kg) measured in the local soil at the old Rudnany mine (Lenka and Danica, 2014). Low levels of zinc increase a person's risk of illness. Zinc plays an important role in maintaining healthy skin. People with long-term injuries often often have low zinc levels, zinc has antioxidant properties, some researchers have suggested that maintaining adequate zinc levels could possibly offer some protection against COVID-19. Zinc is naturally present in all soils in typical background concentrations 10.00 – 100.00 mg/Kg (Mertens and Smolders, 2012). Human activities have enriched the top soils with zinc through the applications of manure or inorganic fertilizers and sewage sludge in the study area.

Table.1. Levels of Selected Heavy Metals (mg/kg) in Street Soil Sediments of Langtang North, Plateau State, Nigeria

Metal Concentrations (mg/kg)								
Fractions	As	Cd	Co	Cr	Cu	Fe	Mn	Ni
Bala	0.00	6.00	15.83	35.17	13.50	24.00	21.33	10.83
Gnagtang	2.50	8.33	3.50	8.67	15.33	11.00	11.17	21.50
She-for	0.83	2.83	2.50	9.00	9.67	10.00	9.67	8.67
Walang	6.17	06.7	1.50	9.83	10.00	22.50	10.83	8.50
Yangang	2.33	8.83	0.00	12.17	12.67	22.17	24.00	12.67
Intorok	1.17	0.67	1.17	3.50	7.33	12.33	5.17	7.00

A. Environment Assessment

Geo-accumulation Index (Igeo):

The I_{geo} includes seven grades: uncontaminated (I_{geo}<0), uncontaminated to moderately contaminated (0<I_{geo}<1), moderately contaminated (1<I_{geo}<2), moderately to strongly contaminated (2<I_{geo}<3), strongly contaminated (3<I_{geo}<4), strongly to extremely contaminated (4<I_{geo}<5) and extremely contaminated (I_{geo}<5).

Table.2. Geo-Accumulation Indices (Igeo) of Some Heavy Metals in the Soil Sediments of Some Streets in Langtang North, Plateau State, Nigeria

Metal Concentrations (mg/kg)								
Fractions	As	Cd	Co	Cr	Cu	Fe	Mn	Ni
Bala	0.00	1.80	2.39	2.05	0.37	0.40	0.83	0.31
Gnagtang	0.43	2.50	0.53	0.50	0.42	0.18	0.43	0.62
She-for	0.14	0.85	0.38	0.52	0.26	0.16	0.38	0.25
Walang	1.06	0.20	0.23	0.57	0.27	0.37	0.42	0.24
Yangang	0.40	2.49	0.00	0.71	0.35	0.36	0.93	0.36
Intorok	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20

V. CONCLUSION

The presence of heavy metals (As, Cd, Co, Cr, Cu, Fe, Mn, Ni, Pb and Zn) has been observed in the sediments of the soil of all the streets. In places where there are signs of organic discharges and domestic sewage, such as Gantang, Yangang and Bala streets, these streets have higher concentrations of heavy metals. The results show that compared to the reference permissible limit reported by the DPR (Adagunodo et al., 2018), the heavy metal content in the streets is relatively low. (2002) and WHO / FAO. (2001/2008). It is worth mentioning that there is a slight risk of toxicity at some points, and the harmful effects caused by the test elements indicate the need to establish a permanent monitoring plan. Studies have shown that metal pollution in the soil is caused by man-made, rather than naturally caused, only slight to moderate man-made changes. The evaluation range of the geo-accumulation index is between 0.00-2.58, with Bala Street being the lowest and Gantang Street being the highest, which means decontamination to heavy pollution. The pollution index of the sediment samples shows that Cr, Zn, As and Pb are the main pollutants. Therefore, it is recommended to further investigate the concentration of other heavy metals in samples from different streets in the study area to determine the accumulation index. Green plants should be used to remove heavy metals and other environmental pollutants from the soil, especially on Bala Street, which has an index of about 3.24. Low pollution areas such as Gantang and Intorok must also maintain a good environmental protection status. Finally, human activities such as industrial and agricultural activities should not be near the streets to avoid excessive accumulation of heavy metals in plants or soil.

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