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HEALTH RISK ASSESSMENT OF PLANTS GROWING AROUND OBAJANA CEMENT FACTORY, KOGI STATE, NIGERIA

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ABSTRACT
Cement manufacturing is identified as a major source of environmental contamination, primarily due to the atmospheric release of heavy metals, plants growing near cement factories are prone to bioaccumulation, which could lead to ecological and human health risk when such plants are consumed. This study was carried out to determine levels of some heavy metals in plants growing around Obajana cement factory using inductively coupled optical emission spectroscopy (ICP-OES) following standard procedures. *Sida acuta* and *Helianthus annus* plants were sampled in this study. The mean concentration of the metals were; 17.82±4.54 (Cu), 48.40±1.81 (Mn), 21.70±7.37 (Ni) and 18.83±3.76 (Pb) mg/kg respectively. The results of the concentration (mg/kg) showed that Ni and Pb exceeded the WHO maximum permissible limit (WHO, 2007) while that of Cu and Mn were below the WHO MPL. Health risk assessment including Hazard quotient (HQ) indicated potential non carcinogenic risk for Adults from Pb while the Cancer risk (CR) revealed cancer risk from Ni for Adults in the study area. These findings highlights the significance of continuous environmental management measures to reduce heavy metal pollution from cement production.

Keywords: health risk, plants, ICP-OES, cement factory, heavy metals.

INTRODUCTION

Cement production is a major contributor to infrastructural growth, but it also represents a significant source of environmental contamination. During manufacturing, large quantities of dust and trace metals are released into the surrounding environment, contaminating air, soils, and water systems (Ayobami *et al*., 2024; Yahaya *et al*., 2024). When soil accumulate heavy metals, it often leads environment contamination and poses significant risks to human health due to its exposure through several pathways such as; direct ingestion, inhalation and dermal contact or through the food chain (Emurotu *et al* , 2022). Plants absorb metals from the soils and as such, the pollution of soils with heavy metals is a significant global concern as it accounts for potential risk to the environment and as well as human health (Navarro *et al*., 2008) The risk of metals in edible parts of crops to humans is a matter of concern, plants growing near cement factories are particularly vulnerable because they can accumulate heavy metals through atmospheric deposition or uptake from soils and water sources that are polluted. As a result, elements such as lead (Pb), copper (Cu), cadmium (Cd), chromium (Cr), nickel (Ni) and zinc (Zn) often bioaccumulate in plant tissues (Laniyan & Adewumi, 2020). Communities around a cement manufacturing industries are at risk of long- time exposure to heavy metals via food chains, since many locally grown plants are taken directly or indirectly as food, medicine, or livestock fodder (Jaishankar *et al*., 2014). Several researchers have established this pattern. Yahaya *et al*. (2024) reported from his study elevated levels of Pb, Cd, Cu, and Zn in food crops from a cement factory in Sokoto State, with health risk indices (HRI) exceeding one, suggesting potential long-term health hazards for consumers. Ayobami et al.(2024) conducted a research around the Ibese cement plant in Ogun State, the findings from this research showed that the levels of most metals were within acceptable limits, but nickel revealed a hazard index above recommended thresholds, underscoring ecological and human health risks. Furthermore, in Ewekoro, southwestern Nigeria, Cr, Cu, Zn, Ni, Co, and Pb in plants and soils were greater than the international permissible levels, with ecological risk indices varying from low to extremely high (Laniyan & Adewumi, 2020).

The adverse effects of these metals have been well documented. Cadmium exposure is linked with renal damage, lead impacts neurological development in children, and hexavalent chromium is categorized as both mutagenic and carcinogenic (Jaishankar *et al*., 2014). Since plants form a major dietary route for environmental exposure to heavy metal, monitoring their contamination is essential for understanding its potential impacts on human health.

Health risk assessment (HRA) facilitates a structured framework to examine such risks by evaluating hazard quotients (HQ), hazard indices (HI), and cancer risk values derived from the measured concentrations of metals and established permissible limits. This is particularly important in rural communities in Nigeria where dependence on locally grown plants for food, medicine, and fodder is high. The plants in this study was selected based on their medicinal properties (Yahaya *et al*., 2024).

Therefore, this study investigated the levels of heavy metals in the selected plants growing around Obajana cement factory, Nigeria.

MATERIALS AND METHOD

Study Area

The research was carried out around Obajana cement factory Kogi State, Nigeria situated at a latitudes within 7◦91'0.6454'' N - 7◦90'22. 3315 N and Longitude 6◦43'10.5438'' E - 6◦44'34.2099''E. The coordinates of each sampling location were recorded using handheld GPS (Garmin Montana 700) (Figure 1).

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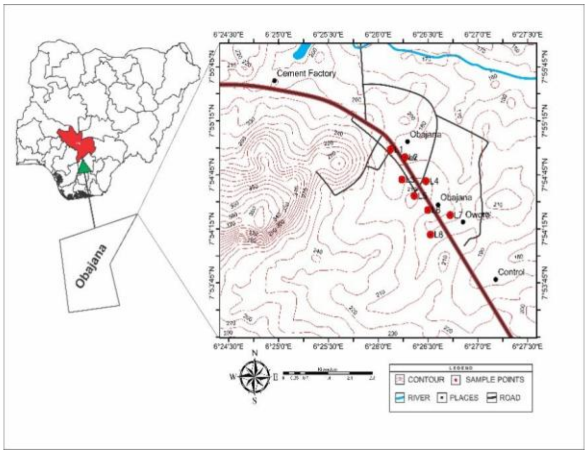

Figure 1: Map displaying the study location
Source: Author's study coordinates (2024)

Obajana is a small community situated in Lokoja local government in Kogi State, north central Nigeria it became popular due to the establishment of Dangote cement factory there, and it is rated as the largest cement manufacturing factory in Africa (Owoleke *et al*., 2023). Obajana has an average maximum temperature of 33^0 C and average minimum temperature of 22.8^0 C. the weather is remains hot year round. The area experiences both wet and dry season (Owoleke *et al*., 2023). Rocks found in the area includes: granulites, quartzite, limestone, schist, granite and pegmatite. (Afeni *et al*., 2008). The soil types are sandy –loam with an average pH of 5.82. The soils are naturally fertile and do not require fertilizers application to obtain a good harvest (Charles *et al*., 2022).

Sample collection
Fresh plants samples of sun flower (*Helianthus annus* and *Sida acuta*) growing along Obajana cement factory, Kogi state was collected. The plant samples were selected based on the information from traditional herbal practitioners on their medicinal properties and its proven efficacy in the treatment of various diseases. The plants were identified by a Taxonomist from the Department of Biological Sciences Federal University of Technology Minna, Niger State.

Sample preparation
The sampled plants leaves were washed with distilled water and spread out for drying at room temperature. The air-dried samples were ground and sieved with a 2 mm mesh and stored at room temperature in polyethylene bags till analysis.

Reagents.
Analytical-grade salts $Cu(NO_3)_2$, $Mn(NO_3)_2 \cdot xH2O$, $Ni(NO_3)_2 .6H_2O$, and $Pb(NO_3)_2$ salts (Sigma-Aldrich, Germany) were used throughout the experiment. A stock solution of 1000mg/L for each metal ion was prepared. The stock solution was diluted with deionized water to prepare the working standard solutions for the calibration curves. The digestion of the sample was done with concentrated HNO_3 and HCl (Sigma-Aldrich, Germany)

Sample digestion
0.5g of the sample was digested with a mixture of concentrated HNO_3 and HCl in a ratio of 1:1. The mixture was heated in a hot plate until a clear solution was obtained. The digest was then transferred into a 50mL volumetric flask and make up to mark with distilled water, the solution was then filtered using Whatman no.42 filter paper. The filtrate was transferred into previously washed polyethylene bottles for ICP-OES (Agilent Technologies 720 ICP-OES) (Amarh *et al*., 2023). Analytical procedures for both standard and blank solution measurement corresponding to each element were done at interval. To validate the quality of the results, standard solutions were analyzed with each batch of about 10 samples for each element. The ICP-OES was set at a UV exposure time of 30 s; UV neb gas flow of 1.5 L min $^{-1}$; UV RF power of 1KW; at 15 s; nebulizer gas pressure at 220 kpa Pump speed at 15rpm and the cool gas flow rate was 0.5 L min $^{-1}$.

Quality assurance and Quality Controls
All analyses were carried out in triplicate, and blanks were included to check the purity of the reagent .Analytical grade chemicals and reagents obtained from Sigma-Aldrich, Germany were employed throughout the analysis. The glass ware was washed with teepol rinsed with HNO_3 solution and then washed in deionized water. Calibration curves were generated using standard solutions of metals while method was validated through evaluation of linearity, precision and accuracy. The quality of the results were determined through recovery studies by analyzing matrix spike for each element. The recovery studies were carried out by adding a known amount of standard solution to the sample matrix before digestion. Average recoveries obtained were within 99.60 ± 1.71 to 100.20± 5.20%.

Statistical Analysis
Statistical analyses were performed using the SPSS statistical program (Version 22 for Windows Chicago, Illinois, USA) and Origin Pro 2024 (Massachusetts, USA) to perform PCA. The magnitude of the linear relationship between the quantitative variables was estimated through Pearson correlation coefficient. PCA analysis was performed to know if the metals sources are lithogenic or anthropogenic (Emurotu *et al*., 2024) and to examine the association among the measured variables.

Health Risk Assessment
Non- carcinogenic Risk Evaluation
The non –carcinogenic risk associated with the consumption of plants contaminated with heavy metal was calculated based on the Estimated daily intake (EDI), Hazard quotient (HQ), and Hazard index (HI). The Estimated Dietary Intake (EDI) in mgkg^{-1} day was evaluated using Equation 1. (Dagnew *et al*., 2023).

$$EDI = \frac{C \times IR \times ED \times EF}{BW \times AT} \times 10^{-3} \quad (1)$$

where C is the concentration of metal in the plant (mg kg^{-1}), IR is the ingestion rate of plants (20 g day^{-1}), EF is the exposure frequency (365 days/year), ED is the exposure duration (70 y), BW is the body weight of exposed adults with a value of 65 kg and AT is the time period over which the dose is averaged (365 days/year x number of exposure years, assuming 70 y) (Guadie *et al*., 2022)

$$HQ = \frac{EDI}{RfD} \quad (2)$$

The RfD values for Cu, Mn, Ni, and Pb were 0.04, 0.14, 0.02, and 0.004 mg kg d $^{-1}$, respectively.
The non-carcinogenic risk can also be described in terms of the hazard index (HI), which is the sum of HQ values for all metals in the plants (Guadie *et al*., 2022).

$$HI = HQ1+HQ2+,...,HQn \quad (3)$$

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Where HQ1 represents hazard quotient for the first metal HQ2 hazard quotient for the second metal, and HQn is the hazard quotient for the nth metal.
HI < 1 means no risk of non-carcinogenic effects, while HI> 1indicates that there is risk of adverse health effects on humans (USEPA, 2002).

Carcinogenic Risk Evaluation
The cancer risk due to consumption of the heavy metals was estimated using Equation 4 &5 below;

$$CR = EDI \times CSF \quad (4)$$

$$TCR = CR1 + CR2 \ldots\ldots CRn$$

Where TCR represents total carcinogenic risk, CR represents the estimated lifetime of an individual to get cancer due to exposure to potentially carcinogenic contaminated plants CSF Ni (0.91), and Pb (0.0085) mg/kg/day) is the slope factor, indicating the estimated lifetime cancer risk linked with oral exposure to a carcinogen based on average human lifespan of 70 years (USEPA, 2002) Carcinogenic risks within 10^{-4} to 10^{-6} are acceptable (Amarh *et al*., 2023).

RESULTS AND DISCUSSION
The concentrations of copper (Cu), manganese (Mn), nickel (Ni), and lead (Pb) were determined in the plants. The concentrations of all the metals analyzed in the plant samples including their World Health Organization (WHO) maximum permissible limits (MPLs) are showed in Table 1.

Table 1: Levels of heavy metals in plant samples n=20

Code	Botanical name	Mean ± SD concentration (mg/kg)			
		Cu	Mn	Ni	Pb
SA	*Sida acuta*	21.03± 3.49	49.68 ±5.32	26.91± 0.85	21.49± 0.74
HA	*Helianthus annus*	14.61± 1.13	47.12± 1.19	16.49± 0.44	16.17± 0.70
Mean		17.82± 4.54	48.40± 1.81	21.70± 7.37	18.83± 3.76
Limit (WHO,2007)		40	500	10	10

SD, standard deviation

Concentrations of heavy metals in plants
Plants absorb nutrients that are essential for their growth through roots from the soil. The plants uptake of heavy metals depend on several factors such as the soil chemistry, industrialization, plant species, agricultural management and environmental conditions (Briffa *et al*., 2020).
The concentration of copper (Cu), manganese (Mn),nickel (Ni) and lead (Pb) in *Sida acuta* and *Helianthus annus* are presented in Table 1.
The mean concentration (mg/kg) of all the analyzed metals were higher in *Sida acuta* than *Helianthus annus* with decreasing order of Mn (48.40) >Ni (21.70)> Pb (18.83)>Cu (17.820) in both plants. With the exception of Cu and Mn, both Ni and Pb exceeded the WHO permissible limits (WHO, 2007), indicating potential contamination risk in the study area.
Copper levels recorded in this study ranged from 14.61 to 21.03 mg/kg with a mean value of 17.81±4.54 mg/kg (Table1). These values were below the WHO maximum permissible limit (40 mg/kg).This implies that Cu contamination is not yet critical. The results from this study are consistent with those reported by Dagnew *et al*. (2023) which was 8.87 to 25.30mg/kg for medicinal plants sampled from Tara Gedama forest, Ethiopia and by Olowoyo *et al*. (2015) for plants (12.18 to 278.40 mg/kg) growing around a cement factory Pretoria, South Africa. However they were higher than those found in medicinal plants reported by Baba & Muhammad (2021) from Nigeria. The variation across studies may reflect differences in soil geochemistry, industrial activities and plant-specific uptake mechanism. Although Copper is an important micronutrient to human life in small doses, it is a major component in cellular metabolism, redox enzyme, and hemocyanin .Excessive quantity can lead to anemia, liver and kidney dysfunction. Humans with Wilson's disease are at greater risk for health effects due to long time exposure to copper (WHO 2005).
Manganese (Mn) concentration in this study ranged from 47.12 to 49.68 mg/kg with a mean of 48.40 ±1.81mg/kg (Table 1), these results were within permissible limits of 500mg/kg (WHO, 2007). Comparable values have been reported for medicinal plants in Ethiopia (29.20- 64.90 mg/kg) (Dagnew *et al*., 2023), while higher levels have been observed in medicinal plants from a mining town in Ghana (20.58- 282.80 mg/kg) (Amarh *et al*., 2023) and in plants growing around a cement factory Pretoria, South Africa (85.40-394.70 mg/kg) (Oluwoyo *et al*.,2015). Mn is essential for both plant and animal growth, serving as a cofactor for many enzymes. However, its deficiency causes severe skeletal and reproductive abnormalities in mammals while excess Mn accumulation leads to neurological disorders in humans (Baba & Mohammed, 2021).
Nickel levels ranged between (16.49-26.91mg/kg) with a mean value of 21.70±7.37 mg/kg
(Table 1). The level of Ni in this study was above the permissible limits of 10 mg/kg (WHO, 2007). Elevated Ni concentrations are of serious concern and this implies significant industrial influence, which could be due to the activities of cement manufacturing taking place in the study location (Okonkwo et al., 2021). Lower Ni content have been reported in medicinal plants from Tara Gedama forest, Ethiopia and plants from a mining town in Ghana (Dagnew *et al*., 2023; Amarh *et al*. 2023),highlighting the severity of Ni enrichment in the study area.
Nickel in small quantity is essential for plants and animals. Nickel is important for the balancing of lipid contents in tissues and for the production of red blood cells. But at high amount, it becomes toxic and leads to serious diseases such as; loss of vision, as well as heart and liver failures (Baba &Mohammed, 2021).
The concentration of Pb recorded in this study ranged from 16.17 to 21.49 mg/kg with a mean of 18.83±3.76 mg/kg (Table 1).The mean concentrations of both plants were above the WHO maximum permissible limit of 10 mg/kg (WHO, 2007). Elevated Pb levels in this study are consistent with values reported by Amarh *et al*. (2023) whose lead concentrations were in the range of 0.63 to 26.40 mg/kg for medicinal plants sampled from Obuasi, Ghana. Oluwoyo *et al*. 2015 reported similar values for Pb levels within the range (5.77 to 52.38 mg/kg) for plants growing around a cement factory in Pretoria, South Africa. Pb has no known nutritional value it is a toxic heavy metals (Onwordi *et al*., 2015). It is carcinogenic, Long-time exposure to lead could cause miscarriage in pregnant women and decrease in the activity of the nervous system (Amarh *et al*., 2023).The elevated Pb observed in this study is likely due to cement dust emissions and vehicular pollution.

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Table 2: Non-cancer risk index of metals in *Sida acuta* and *Helianthus annus*

Metal	*Sida acuta*		*Helianthus annus*	
	EDI	HQ	EDI	HQ
Cu	6.47E-03	1.62E-01	4.50E-03	1.12E-01
Mn	1.53E-02	1.09E-01	1.45E-02	1.04E-01
Ni	8.28E-03	4.14E-01	5.07E-03	2.54E-01
Pb	6.61E-03	1.65	4.98E-03	1.24
HI		2.34		1.71

E represents the exponent of 10^{-yz}

Table 3: Cancer risk index of metals in Sida acuta and Helianthus annus

Metal	*Sida acuta*	*Helianthus annus*
Ni	7.54E-03	4.62E-03
Pb	5.62E-05	4.23E-05
TCR	7.59E-03	4.66E-03

E represents the exponent of 10^{-yz}

Non-Carcinogenic

The result for the non- carcinogenic health risk of the heavy metals is shown in Table 2. From the EDI values recorded, the consumption of these plants is therefore not likely to pose any health risk to the population. The hazard quotient (HQ) which is use to estimates the risk involved due to exposure to a certain metal for a long period of time was calculated from the ADI and oral reference dose. HQ values that are greater than 1 are would lead to health risk to consumers while those with HQ value less than 1 pose no health risk to its consumers. From Table 2, the HQ values for all the metals were below 1 except for Pb in the two plants under study i.e. SA (1.65) and HA (1.24), similar results was reported by Dagnew *et al*. (2023) who reported HQ > 1 in Cd in some medicinal plants growing in Tera Gedama forest, Ethiopia; Yahaya *et al*., (2024) in HQ of heavy metals in food crops growing around a cement factory in Sokoto state. Both plants recorded HI values greater than1. This implies that adults are at non –carcinogenic health risk from Pb via consumption of both plants in the study area.

Carcinogenic Risks

Cancer risk (CR) values less than10^{-6} are considered negligible, those greater than 10^{-4} are un
acceptable, and those within 10^{-4} to 10^{-6} are considered is the permissible range (Amarh et al., 2023).From Table 3, CR values for Ni were above the maximum acceptable limit of 10^{-4} the results of this study is similar with that of Wang *et al*., (2019) in CR value of Cr in children in soil from mining site in china. Which implies that adults are prone to carcinogenic risk of Ni from consumption of both plants in the study area.

Correlation heavy metals in the plants

The extent of correlation between the metals was determined using Pearson's correlation in origin pro 2024 in Figure 2. All the metals show strong positive correlation with each other. Cu shows a strong positive correlation with Mn, Ni, and Pb with the correlation coefficient of 0.83, 0.94, and 0.82 respectively. Similarly there exist a strong positive relationship with the pairs Mn-Ni,Mn-Pb, and Ni-Pb with correlation coefficient of 0.93, 0.80 and 0.83 respectively all $p < 0.05$. The positive correlations found among the metals indicates that they share a common source or chemical similarities (Emurotu *et al*., 2024). Table 4 presented the factor loadings that were computed, the cumulative percentage of variation, and the percentages of total variance explained by each component.

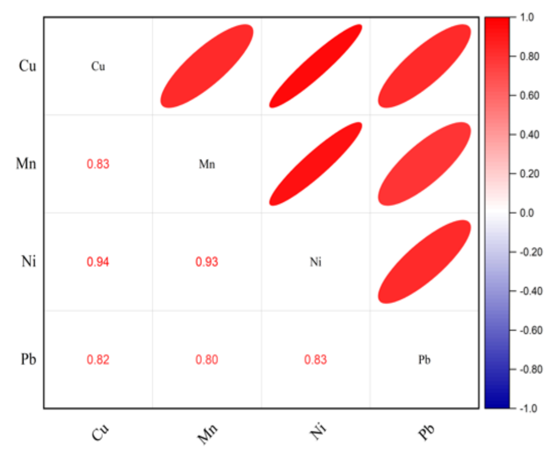

Figure 2: Pearson correlation between the metals in plant samples

The loading plots of the two components are showed in Figure 3. The first factor, which accounted for about 89.31% of the variance overall and had the largest loadings for Cu (0.503), Mn (0.497), and Ni(0.518), was primarily generated from common sources. The second factor accounted for about 5.69% of the total variance, with high loadings for Pb (0.848). The high content of Cu, Mn, and Ni in factor one and Pb in factor two could be due to anthropogenic activities (Okonkwo *et al*., 2021).

Cluster analysis

This analysis was conducted to categorize the analyzed metals. A dendrogram (Figure. 4) showed the metals in three clusters. Cluster 1 has Cu and Ni, Cluster 2 contained only Mn and Cluster 3 has solely Pb. The Cluster Analysis results justify the conclusion that the metals originated from anthropogenic sources.

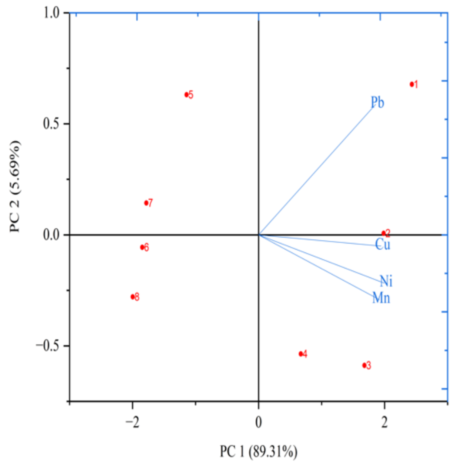

Figure 3: Loading plot of the two component

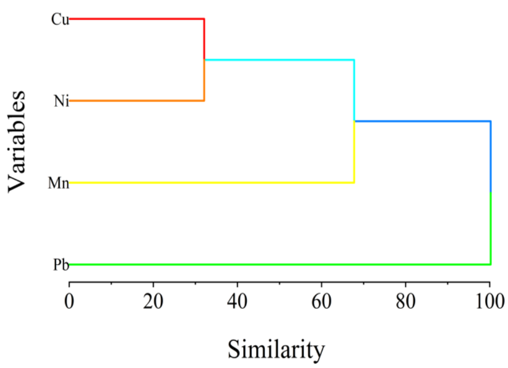

Figure 4: Dendrogram showing clustering of the analyzed heavy metals

Table 4: Principal component loadings for heavy metals

Heavy Metals	PC1	PC2
Cu	0.503	-0.073
Mn	0.497	-0.421
Ni	0.518	-0.314
Pb	0.482	0.848
Eigen Value	3.573	0.228
%Total Variance	89.31	5.69
Cumulative % Variance	89.31	95.00

Conclusion

The level of heavy metal in the plant sample were determined. the concentration of Pb and Ni were above the WHO maximum permissible limit of 10mg/kg in all sample but Cu and Mn were below the WHO permissible limit of 40 and 500 mg/kg respectively health risk assessment revealed HQ values less than one in all metals except Pb and CR showed that Ni was above the maximum permissible limit of 1 x 10^{-4} indicating that the Adults are at non-carcinogenic risk from Pb and Carcinogenic risk of Ni via consumption of the plants from the study area .The findings emphasize the need of adopting sustainable practices in cement industry to safeguard communities that rely on local vegetation.

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