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HEAVY METAL CONTAMINATION AND ASSOCIATED ECOLOGICAL RISK ON FARMS AROUND OLUYOLE INDUSTRIAL AREA, IBADAN

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ABSTRACT

Assessment of heavy metal concentration was done to determine the contamination on various farms around Oluyole industrial area and the corresponding ecological risk they posed in the area. Four farmlands were visited and different plant samples ((Musa acuminata (banana), Saccharum officinarum (sugarcane), Abelmoschus esculentus(okra)and Zea mays (maize)) were collected on each farmland. The plant samples were analysed using Atomic Absorption Spectrometer (AAS) and the data collected were used to analyse the bioaccumulation factor, contamination factor, and ecological risk indices. The metal concentrations result indicates that the significant difference in the heavy metals from each other is at 5% level of significant also the mean separation showing the sequence Cr>Pb>Co>Zn>Cd>Mo>Mn values. Bioaccumulation factor analysis showed that cobalt (5.55) is the heavy metal accumulated the most by the Musa acuminate plants while chromium (0.74) is the metal accumulated the most by the Saccharum officinarum plants. Chromium (1.10) is also the most accumulated by the Abelmoschus esculentus plants while lead and zinc (1.39 and 3.61 respectively) are the heavy metals accumulated the most by the Zea mays plants. The calculated contamination factor showed that Co, Mn, Cr and Cd are the metals showing very high contamination of the plants (CF≥6) while Pb (1.10) showed moderate contamination of the plants. The ecological risk assessment showed that only Cd has very high ecological risk within the four farmlands while the whole industrial area is at a high ecological risk (2094.42) for pollution. Consequently, due to the effects of these heavy metals to the consumers, the farmlands need to be relocated farther from these industrial environments and an environment impact assessment need to be carried out to create awareness to the habitants of this area on the impact of these industrial activities to their environments.

Keywords: Heavy metals, bioaccumulation, contamination, ecological factor

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INTRODUCTION

Heavy metals are naturally occurring elements that are found throughout the earth's crust with high density compared to water. Most environmental contamination/pollution and human exposure result from anthropogenic activities such as mining and smelting operations, industrial production and use, and domestic and agricultural use of metals and metal-containing compounds (He *et al*., 2005). Growth reduction of plants as a result of changes in physiological and biochemical processes in plant growing on heavy metal polluted soils has been recorded (Chatterjee and Chatterjee, 2000; Oancea *et al.*, 2005). Continued decline in plant growth reduces yield which eventually leads to food insecurity. Heavy metal pollution of the environment, even at low levels, and their resulting long-term cumulative health effects are among the leading health concerns all over the world. Heavy metals are known as non-biodegradable, and

or long durations when transported l to plants. Heavy metals such as arsenic, cadmium, lead, chromium, nickel, cobalt and mercury are of concern primarily because of their ability to harm soil organisms, plants, animals and human beings (Adelekan and Abegunde, 2011). Many of them are environmentally persistent and non-degradable contaminants. Initially, they are deposited on the soil surface, then absorbed by the plant roots and further distributed and accumulated into their edible and non-edible parts, posing an imminent danger to the food chain (Ahmad *et al.,* 2019; Alsafran *et al.,* 2021).
Accumulation in living things can occur whenever metals are taken up and stored faster than they are metabolized or excreted (Markich *et al.,* 2001). Bioaccumulation refers to how pollutants (metals) enter a food chain and relates to the accumulation of contaminants, from sources such as water, food, and particles of suspended sediments. Bioaccumulation involves an increased concentration of a metal in a biological organism over time which is in relative to the ambient value. Heavy metals have been known to act as biological poisons, due to their bioaccumulation abilities. Heavy metal accumulation in plants depends upon plant species and the efficiency of different plants in absorbing metals which is evaluated by either plant uptake or soil to plant transfer factors of the metals (Khan *et al.,* 2008). Heavy metals are potentially toxic and phytotoxicity for plants resulting in chlorosis, weak plant growth, yield depression, and may even be accompanied by reduced nutrient uptake, disorders in plant metabolism and reduced ability to fixate molecular nitrogen in leguminous plants (Guala *et al.,* 2010).

Heavy metals, being persistent and non-biodegradable, can neither be removed by normal cropping nor easily leached by rain water (Khadeeja *et al.,* 2013). They might be transported from soil to ground waters or may be taken up by plants, including agricultural crops (Divrikli *et al.,* 2006). A very less amount of heavy metals can also be taken up by vegetables by atmospheric deposition (Prasad *et al*., 2021). Vegetables are major part of human platter as they have high amounts of fibres, minerals, vitamins, and antioxidants. Therefore, heavy metals contamination of plants cannot be ignored due to their significance in food quality assurance.

Furthermore, the food chain pyramid is the track by which biologically toxic trace metals accumulated in humans and other animals (Gupta *et al.,* 2019; Prasad *et al.,* 2021). These accumulations are largely due to high industrial activities introducing high levels of heavy metals to the environments. Plants grown around these industrial areas are likely to take up these metals either from the soil through the roots or from atmospheric contaminants (particulate matters) through the stem and leaves. Plants accumulate these heavy metals from contaminated soil without witnessing any physical change or visible indication, and this could cause a potential risk for humans and animals that will not notice their presence in such plant(s) (Osma *et al.,* 2012). These have made the need to analyze and characterize the heavy metal constituents in farms found around the quarrying industries.

MATERIALS AND METHODS

Study Area

Oluyole industrial area is a known middle-class neighbourhood in Ibadan, Nigeria. The area is filled with numerous artificial activities a mixed use city, mainly consisting of industrial activities, automobile workshop, sewage sludges. Based on 2006 population census its population is 202,725. The industrial market in Oluyole is approximately 351,000sqm (the largest in Ibadan), with the most pronounced industries being Pepsi, Procter and Gamble, Sumal foods group, among others. Materials used in the field work analysis include hand trowel, hand glove, maker, paper tape, nylon, field book and sample bags.

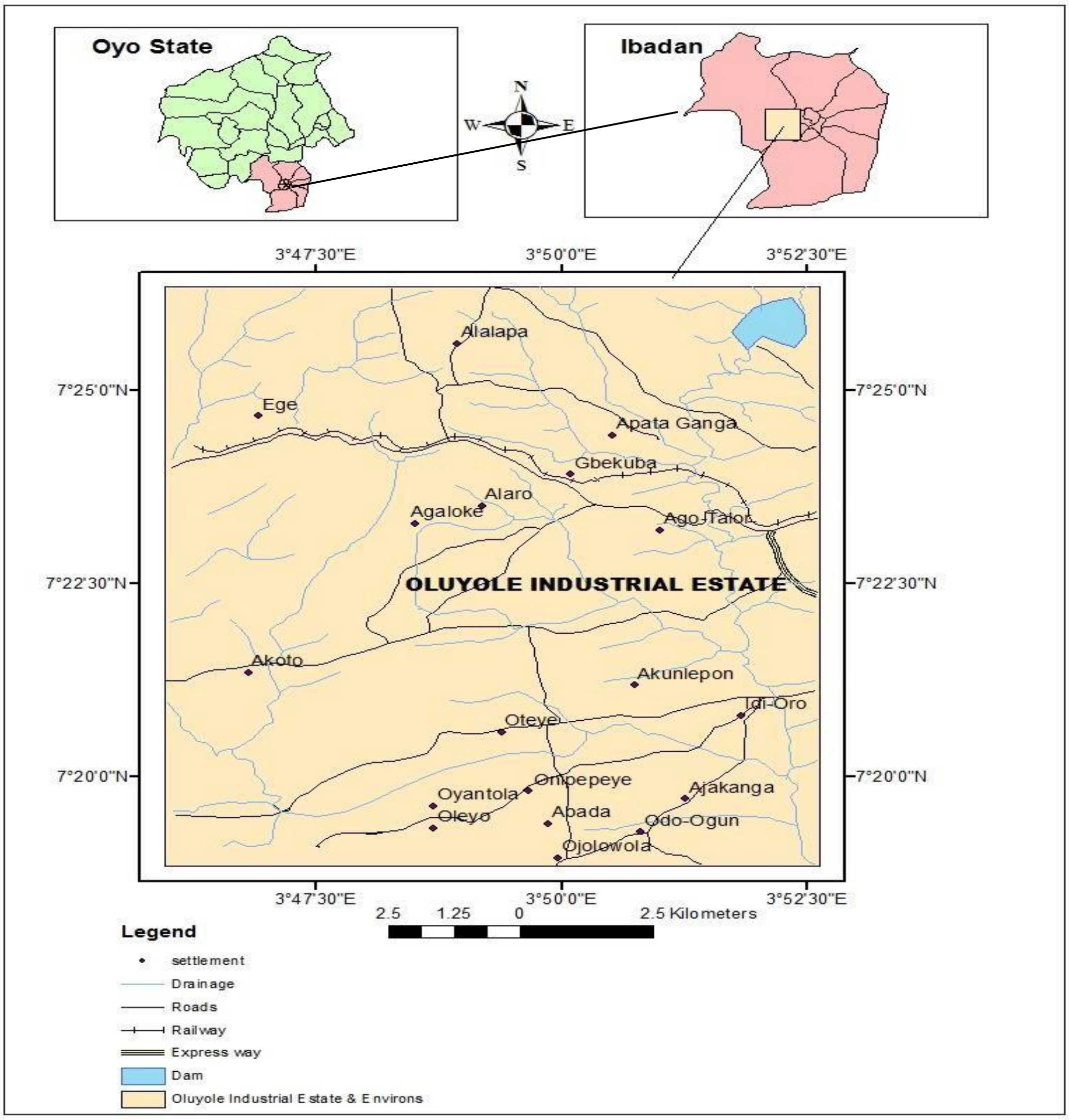

Figure 1: Location Map of the Study Area

Collection of Plant Samples

Four different farms were visited for collection of plant samples. Plants found on each of the farms are *Musa acuminata*(banana), *Saccharum officinarum* (sugarcane), *Abelmoschus esculentus*(Okra) and *Zea mays* (maize). The edible part of the plants was collected randomly, composited and bagged separately according to the various farm plot the plants were harvested. The bagged samples were taken to Institute of Agricultural Research and Training (I.A.R&T) laboratory for elemental constituent analysis. Soil samples were also collected at the spot the plant samples were picked to calculate the bioaccumulation of the heavy metals from the soil to the plants.

Bioaccumulation of Heavy Metals

The Bioaccumulation Factor (BAF) helps to indicate the capacity of crop to take up specific heavy metal with respect to its concentration in the soil substrate (Ghosh and Singh, 2005). It is calculated as;

$$BAF = \frac{Cplant}{Csoil} \quad \ldots\ldots\ldots\ldots (1)$$

Where: Cplant represents the concentration of heavy metal in the plant Csoil represent the concentration of heavy metal in the soil.

Each figure shows the bioaccumulation rate telling the heavy metal that is accumulated most in each plant samples. This helps to identify metals that are taken up and stored faster than they are metabolized. It also helps mobility rate each heavy metal has from soils to the plants.

Determination of Contamination Factor
The contamination factor(CF) calculations were used to know the level of contamination of heavy metals in plants around the area of study and it's express as thus:
CF=$\frac{Mean\ Concentration}{Background\ value}$…… (2) (Hakanson *et al.*, 1980).

The contamination factor classification consists of four classes ranging from low contamination to very high contamination; low contamination (CF < 1), moderate contamination (1≤CF<3), considerable contamination (3≤CF<6), and very high contamination (CF>6).

Ecological risk indices (Er and RI)
Håkanson (1980).
The ecological risk factor (Er) is calculated to express the potential ecological risk each heavy metal has on the plant samples. It is expressed as;
$Er = Tr \times Cf$ ….. (3)
Where Tr is the toxic-response factor for a given substance (Table 1) and Cf is the contamination factor.

Table 1 Toxic-Response Factor for Heavy Metals

Element	Toxic response (Tr)
Pb	5
Co	1
Mn	1
Zn	1
Cd	30
Cr	2
Mo	15

The comprehensive potential ecological risk index (RI) is the addition of Er values which is used to express contamination by heavy metals in a given environment.
$RI = \Sigma Er$ ……… (4)
The different grades for Er and RI are shown in table 2 below.

Table 2 Grades of the Environment by Potential Ecological Risk Indices

Er values	Grades of Er of single metal	RI values	Grades of potential RI of the environment
Er<40	Low risk	RI<95	Low risk
40≤Er<80	Moderate risk	95≤RI<190	Moderate risk
80≤Er<160	Considerable risk	190≤RI<380	Considerable risk
160≤Er<320	High risk	RI>380	High risk
Er≥320	Very high risk		

RESULTS
The summary of heavy metals concentration on plant samples were presented in Table 3. The result revealed significant difference in the heavy metals concentration from each other at 5% level of significant also the mean separation shows the order of Cr>Pb>Co>Zn>Cd>Mo>Mn values were significantly difference from each other on the plant samples in 5% level of significant.

Table 3 Mean Concentration of Heavy Metals in Plant Samples

Plants	Pb mg/kg	Co mg/kg	Mn mg/kg	Zn mg/kg	Cd mg/kg	Cr mg/kg	Mo mg/kg
MA	3.85e	11.1a	1.63g	4.30f	4.18f	6.61e	3.11f
SO	4.04e	2.35e	2.22e	2.62g	3.68g	7.81d	5.23b
AE	6.56d	2.24g	2.17f	5.22d	5.06e	7.68a	7.13d
ZM	8.32f	2.68f	5.22f	5.41f	3.36h	10.35b	1.86g
Mean±SD	19.82±9.7c	15.66±17.5d	8.15±2.5h	13.55±5.9d	13.43±3.6f	29.86±13.9b	10.66±6.1c
RV	18	1	1	99.4	0.2	1.5	15

Means in the same column having the same alphabet are not significantly different from each other at 5% level of significance

RV= Recommended Value (FAO/WHO, 2011.); MA= *Musa acuminate*; SO = *Saccharum officinarum*

AE= *Abelmoschus esculentus*; ZM= *Zea mays*

Table 4 Summary of Heavy Metal Concentration in Soil Samples

Location	Pb mg/kg	Co mg/kg	Mn mg/kg	Zn mg/kg	Cd mg/kg	Cr mg/kg	Mo mg/kg
S_{MA}	9.5c	2.0f	12.5a	12.5a	29.5c	8.5c	17.5a
S_{SO}	13.0b	5.5c	6.5c	10.0b	44.5b	10.5b	12.0c
S_{AE}	19.0a	7.0b	5.0d	8.5c	6.5a	7.0f	17.5h
S_{ZM}	6.0g	4.5f	8.0b	1.5h	24.0d	15.0a	7.0e
∑Mean/SD	44.33±23.4e	16±8.4h	29±19.9g	29.5±19.9g	151±59.1b	38±14.1f	51±21.25d
RV	18	1	1	99.4	0.2	1.5	15

Means in the same column having the same alphabet are not significantly different from each other at 5% level of significant

RV= Recommended Value (FAO/WHO, 2011)

S_{MA}=Soil Samples collected Musa acuminate farm land; S_{SO}= Soil Sample collected at Saccharum officinarumfarm land; S_{AE}= Soil Sample collected at Abelmoschus esculentus farm land; S_{ZM}= Soil Sample collected at Zea mays farm land.

From the calculated means (Table 3), it is noted that the mean concentration of lead (Pb), cobalt (Co), Manganese (Mn), Cadmium (Cd) and Chromium (Cr) (19.82 mg/kg, 15.66 mg/kg, 8.15 mg/kg, 13.43mg/kg and 29.86mg/kg) are greater than their respective recommended values for humans (18 mg/kg, 1 mg/kg, 1 mg/kg, 0.2 mg/kg and 1.5 mg/kg), indicating abnormalities in the concentration of these heavy metals in the plants.

Bioaccumulation of Heavy Metals

Bioaccumulation of the heavy metals was calculated to know the rate with which plants accumulate heavy metals from soils to the plants. This helped to know the metals that are taken up and stored faster than they are metabolized.

Table 5 Bioaccumulation of Heavy Metals in Plant Samples

Metal	Pb	Co	Mn	Zn	Cd	Cr	Mo
BAF_{MA}	0.41b	5.55a	0.13d	0.34bc	0.14b	0.78a	0.18bc
BAF_{SO}	0.31c	0.43bc	0.34b	0.26bc	0.08d	0.74a	0.44a
BAF_{AE}	0.35c	0.32c	0.43b	0.61b	0.78a	1.10a	0.41a
BAF_{ZM}	1.39a	0.60b	0.65a	3.61a	0.14b	0.69b	0.26b

Means in the same column having the same alphabet are not significantly different from each other at 5% level of significant

KEY: BAF_{MA}= Bioaccumulation Factor of *Musa acuminate;* BAF_{SO}= Bioaccumulation Factor of *Saccharum officinarum;* BAF_{AE}= Bioaccumulation Factor of *Abelmoschus esculentus;* BAF_{ZM}= Bioaccumulation Factor of *Zea mays*

The results shown above indicates that in the *Musa acuminata* farm, Co (5.55) is the heavy metal that is accumulated the most while Cd (0.14) is the least accumulated.

Contamination Factor

This was used to know the level of contamination of heavy metals in the selected vegetables using the recommended values (RV) as background values.

Table 6 Contamination Factor of Plant Samples in the Study Area

Metals	Plant Samples	RV
Pb	1.10g	18
Co	15.66e	1
Mn	8.15f	1
Zn	0.14h	99.4
Cd	67.15a	0.2
Cr	19.91c	1.5
Mo	0.71g	15

Means in the same column having the same alphabet are not significantly different from each other at 5% level of significant
RV- Recommended values

The calculated contamination factor (CF) is as presented in table 6. The results showed that Pb, Co, Mn, Cd and Cr are the heavy metals showing significant contamination of the plants in the study area (CF>1) while Zn and Mo showed negligible (CF<1). Only lead is showing moderate contamination (1.10) of the plants while others are showing very high contamination of the plants, according to Hakanson *et al*., (1980) CF classification.

Ecological Risk Indices (Er and RI)

The Er and RI were calculated to know the ecological impact of this contamination caused by the heavy metals on the plants and the environment in general. The Ecological risk indices values for the plants are as shown in the table below.

Table 7Ecological Risk Indices of Vegetable Samples (Er and RI)

Metals	Er	RI	Tr
Pb	5.5g		5
Co	15.66e		1
Mn	8.15f		1
Zn	0.14h		1
Cd	2014.5a		30
Cr	39.82d		2
Mo	10.65e		15
		2094.42a	

Means in the same column having the same alphabet are not significantly different from each other at 5% level of significant
KEY*: Er = monomial potential ecological factor; Tr= Toxic response of factor; RI= Comprehensive ecological risk index*

The calculated monomial potential factor (Er) showed that only Cadmium has very high risk with the plants and environment. The other heavy metals fall within the range of low risk with Cr moving close to moderate risk (39.82). The comprehensive ecological risk index (RI) showed that the plants around the area and the environment as a whole are at high risk of pollution (2094.42). This implies other than the heavy metal studied, the area is at a very high risk of pollution of other elements and compound which will raise the susceptibility to diseases.

DISCUSSION

In the singly metal concentrations (Table 3), it is shown that Pb has highest mean concentration of 8.32mg/kg in the *Zea mays* farm. This is higher when compared with the concentration of Pb in *Zea mays* (1.89 mg/kg) of Aladesanmi *et al*., 2019. Co mean concentration (11.1mg/kg) is highest in the *Musa acuminata* farm and this is higher when compared with Flores *et al*., 2018 (1.89 mg/kg). Mn concentration is also the highest (5.22mg/kg) in the *Zea mays* farms while Cd is highest (5.06mg/kg) at the *Abelmoschus esculentus* farm. This is greater (0.161mg/kg) when compared with that of Zhou *et al.*, 2016 in China. The Cr concentration is highest in the *Zea mays* farms (10.35 mg/kg), it is lower when compared with the concentration of Irfan *et al.*, 2021 (2.95 mg/kg).

In the plant samples, only Co has standard deviation (SD) closer to the means. This indicate that there is uniform source of cobalt toxicity in all the plant farms of the study area and this is basically the emissions and wastes from the industries. Other metals have SDs far to their various means and this indicate that we have others sources these metals (Pb, Cd, Cr, Mn, Zn, Mo) aside the emissions and wastes from these industries. Mn sources may include (aside the industrial wastes) disposal of dry cells batteries from the automobile workshops in the area, soil erosion, and release from waterways of other industries in the area. It is often said that vegetarians often have diets richer in manganese than those who select omnivorous diets. Pb sources may also include burning of refuse, disposal of lead batteries, water pipes. These are other anthropogenic sources and activities found in the study area. Other sources of cadmium found in the area are burning of coal and oil, incineration of municipal wastes, disposal of Ni-Cd batteries while Cr has other sources which include the impair of asbestos that contain chromium, emissions of chromium-based converters, release from vehicular exhaust pipes, and tobacco smoke.

The calculated bioaccumulation factor (Table 5) indicates that Co is the heavy metal that is taken up fastest from the soils to the banana plants and is also the least metabolized of all the heavy metals which makes it to be found most accumulated in the banana plants. Cd which is the least accumulated showed that it is absorbed slowest from soils to banana plant when it is being related with other heavy metals. In the *Saccharum officinarum* farm, Cr (0.74) is the metal with the most accumulation rate while Cd (0.08) is the least accumulated. This also indicate that Cr is the metal that is taken up fastest from the soils to the sugarcane stems and is also the least metabolized while Cd is the metal that is taken up the least when compared with other heavy metals. Chromium (1.10) is also the metal that is accumulated the most in the *Abelmoschus esculentus* farm while Co (0.32) is the metal with least accumulation. This showed that Cr is also the metal that is taken up the fastest from the soil to the vegetable plants while Co is taken up the least. Lead and zinc (1.39 and 3.61 respectively) are the heavy metals that are accumulated the most in the *Zea mays* farm while Cd (0.14) is the least accumulated heavy metal in the maize farm. This indicate that lead and zinc are the metals taken up fastest from the soils to the maize plants with Zn being the fastest. Cadmium is therefore the metal that is taken up from the soils to the plants the least. Consequently, Co has the highest mobility rate in the *Musa acuminata* farm while Cr has the highest mobility rate in the*Saccharum officinarum* farm and *Abelmoschus esculentus* farm. Meanwhile, Zn has the highest mobility rate in the *Zea mays* farm.

Contamination factor analysis indicates that the industrial activities and other anthropogenic activities are adding these heavy metals (especially Co, Mn, Cd and Cr) to the farmlands produces and this will have huge effect on the consumers who are mostly humans while the ecological risk indices showed that the sources of Cd which include the industrial wastes and emissions, burning of coal, incineration of wastes and disposal of Ni-Cd batteries have very great influence in the ecological assessment of the study area more than other anthropogenic activities in the area. It also showed that plants are unfit for consumption. The comprehensive ecological risk index (RI) implies other than the heavy metal studied, the area is at a very high risk of pollution of other elements and compound which will raise the susceptibility to diseases.

CONCLUSION

Heavy metal concentration of plants from four different farmlands around Oluyole industrial estate was revealed various degree of risk indices and need for urgent assessment. The bioaccumulation factor assessments showed that Co is the metal accumulated the most in the *Musa acuminata* farm while Cr is the most accumulated in the *Saccharum officinarum* farm and *Abelmoschus esculentus* farm. Lead and zinc are the most accumulated in the *Zea mays* farm. The calculated contamination factor revealed that only Zn and Mo have low contamination while other heavy metals have significant contamination in the plants. The ecological risk assessment showed that only Cd is showing high risk of ecological pollution in the area while Cr is also moving towards same range while the whole environment can be concluded to be at very high risk. Consequently, the area is concluded not to be safe for the farmlands, the consumers of the farm produce and the habitants of this environment.

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