



The Level and Concentration of Heavy Metals in Fadama Soils and Vegetables along Katako Bridge, Jos Nigeria

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ABSTRACT

The study assesses the concentration of heavy metals in soils and vegetables in Fadama sites along Katako bridge in Jos Metropolis. Samples of vegetables (cabbage and lettuce) and soils were collected from selected Fadama farms and analysis was made for six (6) different heavy metals. These include Lead (Pb), Chromium (Cr), Cadmium (Cd), Copper (Cu), Zinc (Zn) and Nickel (Ni). The study site was subdivided into two located at either sites of the River Delimi. Twelve (12) sample points were chosen for all sides of the river (FGB 1-12) for soil samples while six (6) points were chosen for vegetable samples (FGV1-6). These samples were analyzed in the laboratory for heavy metals using Atomic Absorption Spectrometer (AAS) for soils and vegetables and the results were subjected to statistical analysis of Mean, Standard Deviation, Coefficient of Variation, ANOVA, Correlation and Regression. The findings revealed that Cr and Cd had the highest values of 0.087ppm and 0.04ppm respectively. Comparing these values with WHO standard of 0.05ppm and 0.01ppm shows high occurrence of Heavy metals which may be attributed to the cosmopolitan nature of the area where a lot of human activities are carried out. The study also shows that strong relationship existed between soil and vegetables in the study area, Cu had the highest R^2 value of 0.87 while the relationship between vegetables with Pb, Cd, Zn, Cr and Ni was weak. The study suggested that the use of chemical fertilizers which contain heavy metals should be strictly based on professional advice and that other likely sources of heavy metals such as water were not included in this research but given attention for further study.

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INTRODUCTION

Soil is not only a medium for plants growth or waste disposal but also a transmitter of many pollutants to surface water, ground water, atmosphere and food. Soil pollution may threaten human health not only through its effect on hygiene quality of food and drinking water, but also through its effect on air quality. Little attention has been paid to soil pollution compared to food in the past (Wong, J.C 1996). More recently, however, the impact of soil pollution on soil functions and the biosphere has been increasingly emphasized by the government, environmental

protection agencies and the public (Tiller, K. G 1992). In particular significant advances have been made in respect of mining related heavy metal pollution of the soil in different parts of the world (Jung, M. C 2002).

However, a survey of heavy metals indicates that they do accumulate in soils in some localized areas of human activities as compared to areas that have remained under virgin conditions (Kawai, M. J 2018). In addition to mining activities, concentration of heavy metals in terrestrial environment have increased significantly as a result of human activities such as

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emissions from thermal power stations, waste disposal, soil amendments and vehicle traffic/road infrastructures (Jung, M. C, 2002). Other non-point sources of contamination affecting predominantly agricultural soils include inputs such as, fertilizers, pesticides, sewage sludge, organic manures and composts (Kawai, M. J, 2018). Some of the anomalous accumulation may also be geology-related.

The beneficial and detrimental effects associated with the use of this contaminated water in agriculture are well known. Environmental contamination in some developing countries has been attributed to negative effect of technological developments such as Urbanization and industrialization, with poor planning in waste disposal and management (Rajagana Pathy *et al.*, 2011). The factors that affect the distribution and occurrence of metals in the soil include soil pH, cation exchange capacity (CEC), organic matter content, soil texture and interaction among the target elements (Ojo, 2017).

Heavy metals such as Fe, Cu, Zn, Mn and Ni though essential nutrients at trace levels, however, at high concentrations beyond stipulated levels could be toxic and harmful. Metals such as Pb, Cd and Cr are reported to be non-essential to man (Edebi and Gideon, 2017).

The use of dumpsites as farm land is a common practice in urban and sub-urban centers in Nigeria because of the fact that decayed and composted wastes enhance soil fertility. These wastes often contain heavy metals in various forms and at different contamination levels. Some heavy metals like As, Cd, Hg and Pb are particularly hazardous to plants, animals and humans. Municipal waste contains such heavy metals as As, Cd, Cu, Fe, Hg, Mn, Pb, Ni and Zn which end up in the sink when they are leached

out from the dumpsites. Soil is a vital resource for sustaining two human needs of quality food supply and quality environment.

Rivers are known to be the dominant Pathway for metals transport (Ikhuoriah and Oronsaye 2016) and heavy metals become significant pollutants of many riverine systems. Waste water contains substantial amounts of toxic metal which create problems. Excessive accumulation of heavy metals in agricultural soils through waste water irrigation may not only result in soil contamination but also affect food quality and safety (Nasir *et al.*, 2017).

Due to rapid increase in human population, industrialization, urbanization over the years, human life styles and activities have tremendously affected the environment greatly. One of the most significant impacts is heavy metal pollution of farmlands as it serves as an intimate linkage to human food chain (Hong and Law, 2014). The accumulation of metals in agricultural farmland does not only decrease the productivity and quality of crops grown, but it also threatens the safety of ecosystem and human health in monumental dimension through its adverse effect.

The Study Area

The Jos Plateau is a highland area and is part of the highlands of north central Nigeria (Phillips Howard, 1992a). The study area is located between Lat. 9°49'N to 10°2'N and Long. 8°47'E and 8°65'E. The Plateau surface occupies an area of some 8600km sq (Alford *et al.*, 1979) lying at about 1,200m and rises above 1400m to the south of Barkin Ladi and the east of Jos (Phillips-Howard, 1992a), and is bounded by 300-600m escarpments around much of its circumference (fig.1).

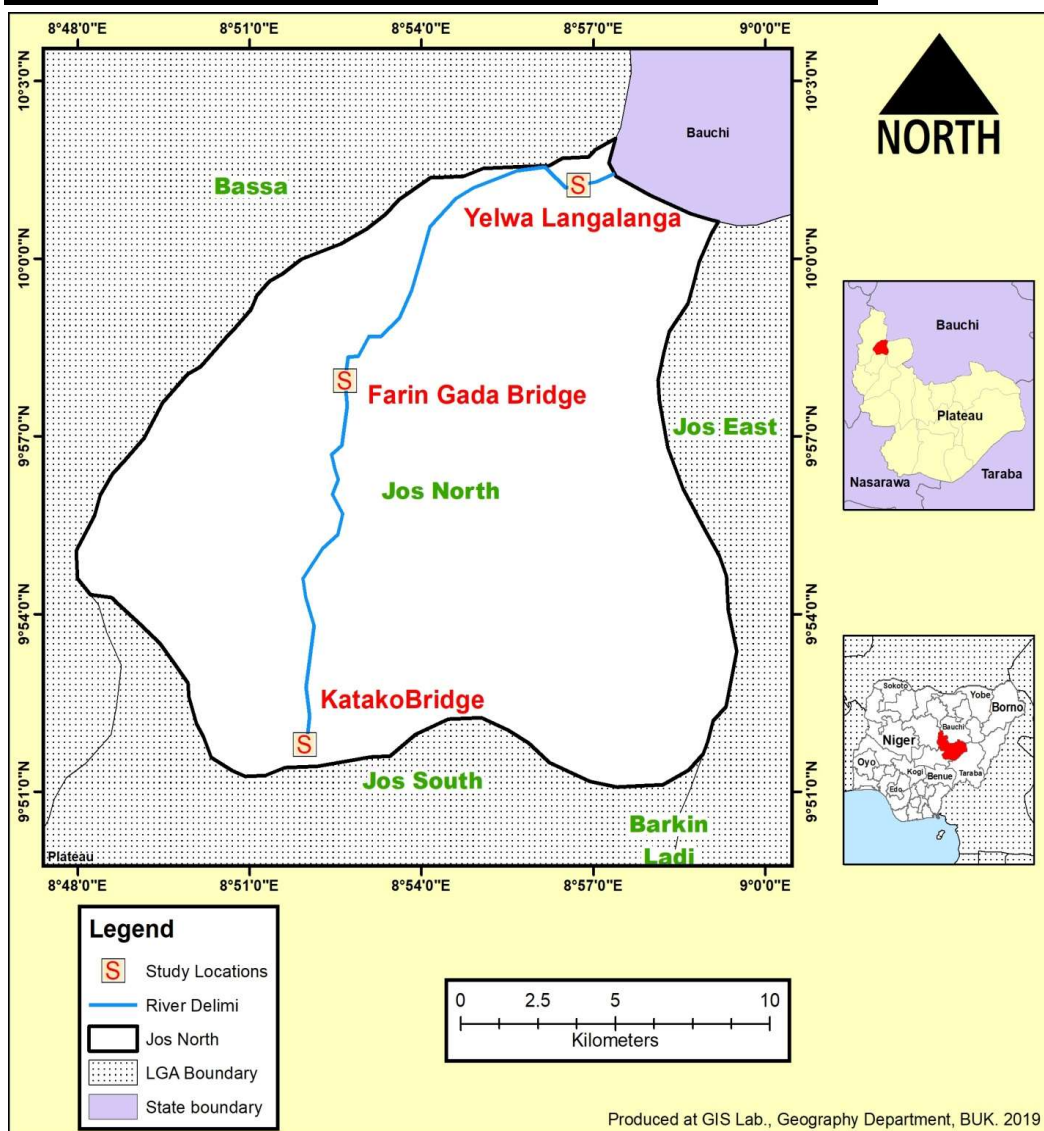


Fig. 1: Map of Jos showing River Delimi and Sampling Sites

The Plateau is characterized by three main rock types: the Basement Complex rocks (which include Older Granites and metamorphic rocks) that underlie more than half the Plateau; the Younger Granites and the Older and Newer Basalts (Phillips-Howard, 1992a; Alford *et al.*,

1979). The Post-Older Basalt Unconsolidated Deposits are particularly important as they form the parent material of many soils on the Jos Plateau. They are divided into the Rayfield, Bokkos and Bisichi Deposits and Ngell Alluvium (Alford *et al.*, 1979).

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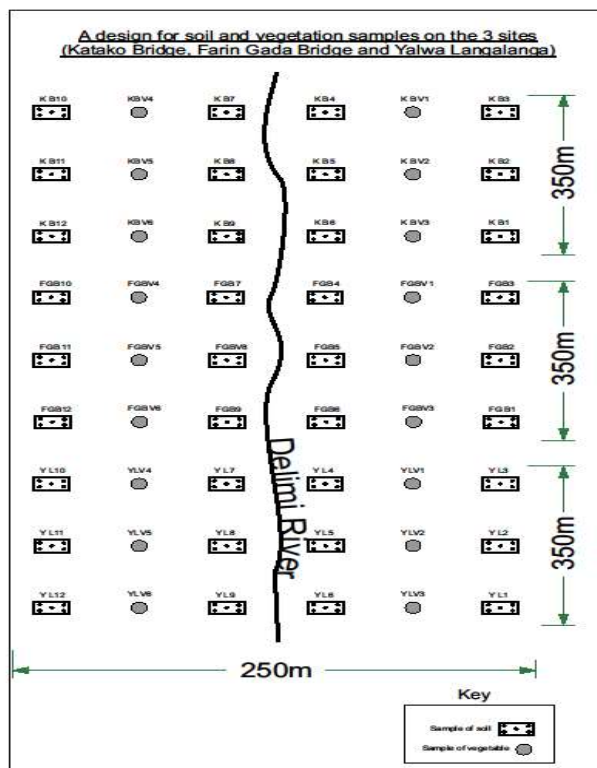


Fig. 2: A design for Soil and Vegetable samples along Farin-Gada Bridge

The Jos Plateau is considered the 'hydrological centre' of the country. The drainage is radial and the watersheds of three major river systems of the country come together at a point near Rayfield. The Delimi River drains to Lake Chad; the Gongola, Wase, Shemankar, Ankwe and Mada Rivers drain into the Benue, and the Kaduna River into the Niger (Alford *et al.*, 1979).

Jos, at an altitude of 1,285m has a mean annual temperature of 21.8°C, ranging from 20.2°C to 24.3°C (mean monthly temperatures). Mean annual rainfall is 1,413mm and the rainy months (May to September) are each characterized by approximately 200 to 300mm (the peak rainfall period is July, with 321 mm). Outside of these months, rainfall drops off sharply (Alford *et al.*, 1979). Higher rainfall may occur

locally around the Shere Hills. The rains start in April and stops in October.

The Scope of the Study

This research is based on data from Katako Bridge linking Farin Gada, to Delimi Langalanga. This area has also been variously referred to by other researchers as Delimi or Delimi Yelwa from the village where most of the farmers live, (Phillips-Howard, 1992b). The site is located along the Delimi River, to the north of Jos and extends northwards from the University of Jos Senior Staff Quarters. The vegetables under study was leafy vegetable-Cabbage (*Brassica oleracea*) which is widely consumed within and outside Jos metropolis. The analysis focused on six metals. These include: chromium (Cr), Copper (Cu), lead

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(Pb), Cadmium (Cd), Zinc (Zn) and Nickel (Ni) found in the soils and vegetables. These samples of vegetables and soils were taken in February through March for analysis before the rains set in.

MATERIALS AND METHODS

Sampling

Soil samples were taken at the depths of 20cm for all the sample points. The vertical distances are 200m and 100m horizontal intervals. Samples were collected into polyethylene bags, labeled and properly tied. In the laboratory, the soil samples were spread on glass plates and then dried in an oven at 60°C for six hours. The dried soil was grounded and sieved through 2mm mesh sieve. Analysis of heavy metals was done for Cd, Cr, Ni, Zn, pb and Cu.

Having selected the 3 sites using GPS and Remote Sensing, the sites were mapped and further sub divided into plots at the left and right sides of the river banks, 10m away from the river. The sites range from 2-3 ha in size. Each site (location) was then divided into plots where twelve (12) sample points were selected for soil samples, six points at either side of the river (fig 2). For vegetable samples, six (6) points each were selected for each location, three (3) points in each side of the river. All these were done using stratified sampling technique for point composite. Each sample point was 100m separated from the other for soil samples and 200m for vegetable samples in all the sites.

In all, 12 samples of soil were taken from each location giving a total of 36 sample points while 6 sample points were taken from each location for vegetable samples giving a total of 18 sample points using random sampling technique to select 3 samples each of leafy vegetables (Cabbage) for the study. The exact sampling sites were established using GPS (fig. 1) in order to get the exact location of the sampling sites.

Samples of leafy vegetables (Cabbage) were collected into labeled polythene bags and taken to the laboratory for analysis of heavy metals (Cu, Cr, Pb, Zn, Cd and Ni).

Soil Laboratory Analysis

One gram each of the ground soil samples was weighed into a 125 ml beaker and

digested with a mixture of 4 ml, 25 ml and 2 ml each of concentrated HClO₄, HNO₃ and H₂SO₄ respectively, on a hot plate in a fume cupboard. On completion of digestion, it was cooled and 50 ml of de-ionized distilled water was added and then the samples filtered. The samples were made up to 100 ml with de-ionized distilled water and concentrations of the elements determined using atomic absorption spectrophotometer (AAS Model SP 9 Unicam 1984). This analysis was done at the National Research Institute for Chemical Technology (NARICT) Zaria for analysis of heavy metals in soils, vegetables and physiochemical characteristics of soil.

Vegetable Laboratory Analysis

One gram (1gm) each of milled/grounded homogenized samples will be weighed with a digital weighing balance into a conical flask and digested in a mixture of 4ml, 25ml, 2ml and 1ml of concentrated HClO₄ and 60% H₂O₂ respectively, at 100°C on a hot plate for two hours in a fume cupboard. The resulting solution was left over night and made up to 100ml with deionized distilled water and concentrations of the elements were determined. The guidelines for Maximum Limit (ML) of heavy metals in vegetables were adopted from WHO standard and FAO/WHO (2007). This analysis was done at the National Research Institute for Chemical Technology (NARICT) Zaria to determine the heavy metals (Cu, Cr, Pb, Zn, Cd and Ni) in soils and vegetables under study using the Atomic Absorption Spectrophotometer (AAS).

Both descriptive and inferential statistics were used for this research. Mean, standard Deviation and descriptive statistics were used for this research using SPSS software (version 16.0) to calculate the coefficient of variation, mean and standard deviation of each heavy metal (ppm) in soils and vegetables.

RESULTS AND DISCUSSION

Levels and Concentration of Heavy Metals in Soils of Fadama at Katako Bridge (KB)

Table 1 reveals that Lead (Pb) has the highest mean concentration of 0.092ppm at Katako bridge, Chromium (Cr) has 0.087ppm at Farin Gada bridge as against Copper (Cu) which

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has the lowest mean concentration at 0.01ppm. Comparing these values with WHO/FAO Max permissible levels of 0.1ppm and 1.5ppm of pb and Cu respectively, it shows that the concentration of Lead (Pb) in the soil is close to the maximum permissible level of 0.1, while that of Copper (Cu) is highly negligible. The result also

reveals that the coefficient of Variation (CV) is highest in Cadmium at 99.68%. That implies that Cd has more variation relative to the mean. By this result it is evident that household materials, spear parts from mechanic workshop (battery, paints) have significant impact on the soil are prevalent in the location.

Table 1: showing the Mean, Standard Deviation and Coefficient of Variation of soils along Katako Bridge

Metals	Pb	Cd	Zn	Cu	Cr	Ni
Mean (ppm)	0.0214	0.04	0.02	0.089	0.087	0.0105
Std. Dev	0.01	0.04	0.00	0.00	0.05	0.01
CV%	10.86	99.68	12.81	28.60	57.47	100.0
WHO Permissible Level	0.1	0.01	15.0	1.50	0.05	6.5

Source: Field and Lab work, 2018.



Fig. 3: Map of Katako Bridge showing Fadama Site

Source: Google Earth, (2022).

Levels and Concentration of Heavy Metals in Vegetables at Katako Bridge (KB)

From the table, the concentration of heavy metals is highest in lead (Pb), having a

mean concentration of 1.019ppm and 0.978ppm in cabbage and lettuce respectively at katako bridge. The least concentration occurred in Copper (Cu) with mean concentrations at

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0.145ppm and 0.142ppm in cabbage and lettuce respectively. Comparing these values with WHO standards, it is evident that lead (Pb) exceeded its threshold limits of 0.3ppm for both vegetables. The location of this agricultural site in the urban area is the reason why Lead (Pb) is the dominant heavy metal. The table also reveals that the CV for Cu and Ni are 89.65% and 83.59% respectively indicating a deviation from the mean than other metals while the metal with the least CV is Cadmium (Cd) with a value of 6.13%. The metals in the vegetables at this location are in the order

Pb>Ni>Zn>Cr>Cu>Cd in both cabbage and lettuce.

Adelakan *et al.*, (2011), conducted a study on heavy metal contamination of soil in Ibadan and discovered that these high values may be attributed to human indiscriminate disposal of wastes from homes and mechanic workshops. Sources of lead include; leaded paints, Cans, plumbing fixtures, leaded gasoline, deterioration of leaded paint used in the past, soldering, and vehicle exhaust and lead crystal.

LEVELS AND CONCENTRATION OF HEAVY METALS IN VEGETABLES

Table 2: Levels and Concentration of Heavy Metals at Katako Bridge (KB)

Points	Pb		Cd		Zn		Cu		Cr		Ni	
	Cb	Lt	Cb	Lt	Cb	Lt	Cb	Lt	Cb	Lt	Cb	Lt
KB1	1.005	0.997	0.091	0.086	0.427	0.396	0.011	0.09	0.211	0.2	0.784	0.676
KB2	1.112	1.099	0.102	0.098	0.119	0.108	0.033	0.031	0.191	0.203	0.654	0.916
KB3	0.997	0.872	0.104	0.121	0.106	0.103	0.103	0.093	0.227	0.215	0.152	0.188
KB4	0.821	0.806	0.087	0.076	0.278	0.265	0.101	0.13	0.193	0.199	0.263	0.157
KB5	1.201	1.199	0.117	0.109	0.283	0.277	0.412	0.311	0.185	0.187	0.049	0.864
KB6	0.978	0.899	0.182	0.167	0.11	0.108	0.212	0.199	0.19	0.187	0.049	0.864
Mean	1.019	0.978	0.1138	0.109	0.2205	0.209	0.145	0.142	0.199	0.198	0.323	0.610
WHO standard	0.3	0.3	0.2	0.2	99.4	99.4	1.21	1.21	0.130	0.130	1.00	1.00

Source: Researcher's data (2018)

From the table above, the concentration of heavy metals is highest in lead (Pb), having a mean concentration of 1.019ppm and 0.978ppm in cabbage and lettuce respectively at katako bridge. The least concentration occurred in copper with mean concentrations at 0.145ppm and 0.142ppm in cabbage and lettuce respectively. Comparing these values with WHO standards, it is evident that lead (Pb) exceeded its threshold limits of 0.3ppm for both vegetables.

These high values could be attributed to human the indiscriminate disposal of wastes from homes and mechanic workshops. Sources of lead include; leaded paints, cans, plumbing fixtures, leaded gasoline, deterioration of leaded paint used in the past, soldering, vehicle exhaust, lead crystal; The metals in the vegetables at this location are in the order Pb>Ni>Zn>Cr>Cu>Cd in both cabbage and lettuce.

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Levels and concentration of Heavy Metals in Soils of Fadama.

Table 3. Katak Bridge (KB)

Points	pb	Cd	Zn	Cu	Cr	Ni
KB1	0.1	0.004	0.0113	0.0003	0.0249	0.089
KB2	0.0813	0.005	0.015	0.0107	0.0741	0.0531
KB3	0.2097	0.0056	0.0175	0.0125	0.122	0.043
KB4	0.2154	0.0219	0.0235	0.0066	0.0163	0.0111
KB5	0.2132	0.0028	0.0273	0.0007	0.1491	0.0196
KB6	0.1868	0.0025	0.024	0.0051	0.1205	0.0518
KB7	0.0128	0.1439	0.011	0.0002	0.0198	0.0083
KB8	0.0035	0.0247	0.0149	0.0098	0.0697	0.0027
KB9	0.0454	0.1651	0.0162	0.0116	0.1198	0.0009
KB10	0.0145	0.012	0.0231	0.0086	0.0156	0.0089
KB11	0.0321	0.1031	0.0268	0.0006	0.1344	0.0198
KB12	0.0197	0.0321	0.021	0.0049	0.1198	0.0016
Mean	0.095	0.044	0.0193	0.006	0.082	0.025
WHO Max level in soil	1.0	0.3	3.0	1.0	1.0	0.5

Source: Researcher's data (2018)

The table above reveals that Lead (pb) has the highest mean concentration of 0.0945ppm, Chromium (Cr) has 0.0821ppm as against Copper (Cu) which has the lowest mean concentration at 0.00596ppm. Comparing these values with WHO/FAO Max permissible levels of 0.1ppm and 1.5ppm of pb and Cu respectively, it shows that the concentration of pb in the soil is above average while that of Cu is low. By this result it is evident that household materials, spare parts from mechanic workshop (battery, paints)

have significant impact on the soil at Katak Bridge.

Correlation between metals in soil and vegetable

The relationship between heavy metals in soil and lettuce was determined using was evaluated using correlation statistics and presented in Table 9 which shows that there is a strong relationship existing between some heavy metals in soil and vegetable in the study area.

Table 4: Correlation between Metals in Soil and Lettuce

Heavy metals	Correlation coefficient (R ²)	p-values
Pb	0.17442	1.07E-06
Cd	0.239226	0.000167
Zn	0.0044242	0.310158
Cu	0.87763	0.008482
Cr	0.176473	0.000154
Ni	0.560795	0.000423

Source: Researcher's Data (2018)

The study revealed that very strong relationship existed between heavy metals in Cu (0.87763) in soil and vegetable. Increase in heavy metals in soil can lead to a corresponding increase in heavy metals in vegetable. Similarly, a moderate relationship existed in Ni (0.560) in soil and vegetable. The results further depict that a

weak relationship existed between heavy metals in soil and vegetable in Zn (0.00442), pb (0.17), Cr (0.1764) and cd (0.23922). The p-values are high in pb (1.07E-0.6) and Zn (0.31015) but low in the other heavy metals.

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Coefficient of Determination of Heavy Metals in soil and Vegetables

The relationship of heavy metals in soil and cabbage was evaluated using coefficient of

determination and presented in Table 10 where the results revealed that relationships existed between heavy metals in soil and vegetable.

Table 5: Coefficient of Determination of Heavy Metals in Soil and Vegetable

Heavy metals	R ²	Adjusted R	Standard error of Estimate
Pb	0.026	-0.0026	0.4492
Cd	0.078	0.0505	0.0479
Zn	0.064	0.003	0.228
Cu	0.086	-0.030	0.33
Cr	0.000	-0.029	0.050
Ni	0.011	-0.018	0.202

Source: Researcher's Data (2018)

The results revealed that Cu had the highest R² value of 0.86 while the relationship between cabbage with other heavy metals (pb, cd, Zn, Cr and Ni) was weak. This implies that Cu in soil affects Cu in vegetable and the relationship is significant. The adjusted R in Cd (0.050) was high, hence, increase of heavy metal in soil does not cause any increase in vegetable except in the case of Cu.

CONCLUSION

Based on the findings, it can be concluded that heavy metals were detected at all the study locations in soils and vegetables, though at different proportions, however, the concentrations were more in vegetables. Metals like Lead (Pb), Cadmium (Cd) and Chromium (Cr) were seen to have occurred above WHO standards, thereby constituting a serious health hazard to consumers. This was attributed to the fact that the use of farm inputs such as fertilizers, herbicides and fungicides increase the chances of adding heavy metals to the soil.

In order to create a sustainable agriculture, environmental balance and food security, the following recommendations were suggested:

- i. Environmental Protection Agency which is saddled with the responsibility of sensitizing farmers and consumers on the harmful effect of consuming vegetables that contain heavy metals should step up their campaign to reduce the risk of contracting diseases.

- ii. In order to maintain soil fertility, inorganic manure such as farm yard manure, compost and slash and burn ash should be used. In this way alone, soil fertility can be maintained provided it is available in sufficient quantity. The use of chemical fertilizers which contain heavy metals should be strictly based on professional advice.
- iii. The cultivation of certain crops that are known not to accumulate heavy metals should be encouraged and their metabolic mechanisms studied. Those that accumulate a lot of heavy metals should be avoided or improved. Crops to be planted in this environment should be heavy metal resistant.
- iv. This research was based on two parameters i.e soil and vegetables. Further study could include water to actually ascertain its level of toxicity and consequent harmful effect on humans.
- v. Research should be carried out regularly to ascertain the level of pollution of heavy metals in the environment.
- vi. Further research on heavy metals should be done at greater soil depth.

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