HEAVY METAL CONTAMINATION OF VEGETABLES PLANTED IN LAGOS SOILS AND THEIR POTENTIAL POLLUTION RISKS

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ABSTRACT

Vegetables can play an important part in alleviating hunger and malnutrition in Nigeria, because they are among the basic requirements of balancing our diet. They have adequate nutritious supply and with characteristic taste. However, vegetable could serve as a source of toxic metals in human especially when planted in contaminated soils. The implications associated with metal contamination are of great concern. This study evaluated edible vegetable samples harvested from suspected contaminated soils located at: Iyana-Iba, Baruwa-pipeline, Isheri-Oshun and Idi-Araba. The plants and their corresponding soil samples were collected and acid-digested. The following parameters: Cu, Zn, Ni, Fe, Pb, Cd, and Cr were determined in the digested samples with Atomic Absorption Spectrophotometer. The metals were found in the decreasing order of concentrations as follow: Iyana-Iba (Fe > Cr > Pb > Zn > Cu > Ni > Cd), Baruwa pipeline (Fe > Pb > Zn > Cr > Cu > Ni > Cd), Isheri-Oshun (Fe > Pb > Cr > Zn > Ni > Cu > Cd); Idi-Araba (Fe > Cr > Pb > Zn > Ni > Cu > Cd). Using enrichment factors, all the samples were severely enriched with Cd and Pb. The edible parts of vegetables also indicated higher concentrations of Cd (1.13-2.39 mg\kg), Cr (1.58-2.51 mg\kg) and Pb (14.15-43.05 mg\kg) than the WHO regulatory standards implying risk to the consumers. Sources of these metals were traceable to urban storm water, water irrigation and atmospheric deposition. This suggests that farmlands in Lagos should be regularly monitored.

Keywords: Edible vegetables, soils, heavy metals, Atomic Absorption Spectrophotometer

INTRODUCTION

Vegetables are required as basic parts of dietary supplies especially in Nigeria, which has the second highest burden of stunted children in the world. Vegetables are rich in vitamins, minerals, fibres, and phytochemicals which are the sources of antioxidants, phytoestrogens and anti-inflammatory agents (Slavin and Lloyd, 2012). The mineral components of vegetables are linked to certain essential heavy metals. These metals are important for proper formulations of basic compositions necessary for adequate growths, enzymatic functions, regulation of the osmotic pressure and supporting genetic material integrity in the body (Oves *et al.*, 2016). Metals such as Ni, Zn, Cu, and Fe have also been found to be toxic when accumulated in high quantity in the body (Rahman *et al.*, 2014). Non-essential metals such as Cr, Ni, Pb, Cd among others, have yet unknown basic functions and have been found toxic even at low concentrations (ATSDR, 2012a). Both essential and non-essential metals are parts of the natural compositions of the soil where they are found in a quantity not usually harmful. However, they have been continuously accumulated due to urban enlargement and increasing industrialisation (Radulescu *et al.*, 2013).

Heavy metals are toxic, persistent and can easily bio-accumulate in the ecosystem. They have been linked to several chronic diseases such as cancer, organ damages and breakdown of central nervous system and for this purpose heavy metals must be regulated (ATSDR, 2007, 2012a). While the presence of heavy metals in vegetables certifies them as sources of minerals in human nutrition, excessive amounts in edible vegetables could significantly pose serious threat to human health. The potency of this effect is aggravated by poor elimination processes of some heavy metals from the human body (Ghosh *et al.,* 2012).

Many studies have implicated vegetables as major sources of heavy metals in dietary intake (Tripathi *et al.*, 1997; Chang *et al.*, 2014; Osundiya *et al.*, 2014) and vegetables grown in soils contaminated with heavy metals have been found to contain higher concentrations than the vegetables grown in uncontaminated soils. Leaf vegetables have also been reported to accumulate higher concentration of heavy metals than root and fruit vegetables. This condition is related to high translocation rate and high transpiration rate in leafy vegetables compare to other vegetables. It is also well known that plants accumulate metals differently in different parts; Cd and Pb have been reported to preferably accumulate in shoots more than roots. Also, the accumulation of Cd, Cu, and Zn in the edible parts was much greater than that of Pb (Zou *et al.*, 2006; Ngole, 2011; Wang *et al.,* 2012; Chang *et al.*, 2014; Zhou *et al.*, 2016). Plants can take up metals through different mechanisms such as: absorption, ionic exchange, redox reactions, and precipitation – dissolution of metals. These reactions are closely dependent on minerals in soil, soil organic matter, soil pH, redox potential, soil temperature and humidity (Smical *et al.*, 2008). Lagos State is often referred to as one of the most industrialized cities in Africa with high human population. However, factors such as heavy traffic, industrial emissions, unwholesome irrigation water and open space wastes disposal which are known to contaminate the soil (Jiang *et al.*, 2006; Galala and Shehata, 2015) are common practices in the city. They are largely due to the extensive population pressure and increase in anthropogenic activities. Since the State is surrounded by the Lagoon, lands for substantial agricultural purpose are limited. Many of the sites used for subsistence and commercial farming are most likely polluted and by uptake mechanism, the cultivated vegetables are likely to be contaminated, leading to food poisoning. *Amaranthus viridis, Celosia argentea, Corchorus olitorius, Lactusa sativa, Telfairia occidentalis, Allium tricoccum and Talinum triangulare* are commonly grown vegetables in Lagos. This is due to their nutritional values, characteristic tastes and the potency of some for common local medications (Kagaru *et al.*, 2015), and have been used for the same purposes. Since, these vegetables are being cultivated and sold quarterly, information regarding their pollution trend and pollution level of the soil on which they were grown are needed to ascertain, if they are safe for consumption. Previous studies targeted pollution profiling of plants grown on Lagos soil and sources of contamination were irrigation water, atmospheric deposition and general activities around the farming areas (Atayese *et al.*, 2008; Olu-Owolabi *et al.*, 2012; Shan *et al.*, 2013; Osundiya *et al.*, 2014). Further studies are, however, required on sources and effective risk control measures. Investigating and identifying the pollution level and patterns of accumulation of heavy metals such as Cd, Cr, Cu, Fe, Pb, Ni and Zn in the commonly cultivated vegetables will be more helpful in terms of risk assessment. The present study was therefore aimed at identifying the degree of heavy metals present in the tissues of *Amaranthus viridis, Celosia argentea, Corchorus olitorius, Lactusa sativa, Telfairia occidentalis, Allium tricoccum and Talinum triangulare*, as well as in their cultivated soils.

MATERIALS AND METHODS

Study area

The samples were collected at four different sampling sites in Lagos, Nigeria. The sampling sites were selected based on the level of anthropogenic activities, and they are as follow; Iyana-Iba (latitude 6.482°N and longitude 3.200°E), Baruwa pipeline (latitude 6.594°N and longitude 3.272°E), Isheri-Oshun (latitude 6.511°N and longitude 3.292°E) and Idi-Araba (latitude 6.514°N and longitude 3.356°E) were assessed and samples retrieved. Baruwa Pipeline location is by the road side of a residential area with proximity to an auto mechanic workshop. Idi–Araba is located in a densely populated area and is quite close to a major road and public bus park. Iyana–Iba is also located in a densely populated area and close to a major road. Isheri-Oshun is in a new town and scarcely populated. The size of each of the sampling locations ranges from 5 to 10 hectares of land.

Soil and Vegetable Sampling and Processing

Healthy vegetables and rhizosphere soil samples (representative of the farmlands) beneath the plants were taken from four pre-existing farmlands. 50 stands of each plant species were chosen based on the predominated sample population in each location. *Amaranthus viridis, Celosia argentea, Corchorus olitorius, Lactusa sativa, Telfairia occidentalis, Allium tricoccum*, and *Talinum triangulare* were sampled at Iyana-Iba; *Amaranthus viridis, Celosia argentea, Corchorus olitorius, Telfairia occidentalis and Talinum triangulare* were sampled at Baruwa pipeline; *Amaranthus viridis, Celosia argentea, Corchorus olitorius, Telfairia occidentalis* and *Talinum triangulare* were sampled at Isheri-Oshun; while *Amaranthus viridis, Celosia argentea, Lactusa sativa* and *Allium tricoccum were sampled* at Idi-Araba. However, fertilizer was never added to the soil. Plant at harvest stage was chosen and the edible shoot was carefully broken away from the parent plant using vinyl gloves. Decayed parts were carefully removed before the plant was rinsed with de-ionised water and kept in a clean and acid rinsed polythene bag. The soil samples beneath the plants were taken within the depth 0 – 15 cm with hand trowel. Debris were removed from the soil samples before carefully packed in polythene bag. The soil and plant samples were kept separately in iced bags and transported to the laboratory.

Sample Analysis

Five grams of the rhizosphere soil were air dried for 4 – 5 days in the laboratory until constant moisture contents were observed. The air-dried samples were subsequently homogenised with a pre-cleaned ceramic-coated mortar and pestle before manual sieving in < 2 mm sieve. One gram of the sieved samples was digested with 15 mL freshly prepared aqua regia (1:3, HNO_3/HCl v/v – 5 mL HF) according to Okoye *et al.* (1991). HCl was omitted for the determination of Pb to avoid the formation of insoluble lead chloride precipitate. The digested solution was filtered through Whatman filter paper No. 42 into a 50 mL flask and then made to mark. Zn, Ni, Fe, Pb, Cu, Cr and Cd in the digested samples were determined with Atomic Absorption Spectrophotometer. For soil pH, 5 g of air-dried soil was measured into 12.5 mL distilled water. The resulting slurry was mixed properly, and the pH was determined with pH meter. The pH meter was previously calibrated with buffer solutions at pH 4 and pH 7. The cation exchange capacity of the soil was determined using ammonium acetate method already described in USEPA (1986).

Plant analysis was carried out using edible biomass which was rinsed thrice with deionised water before being dried in an oven at 40 °C for about twelve hours. The dried samples were homogenised and 1g of the homogenised portion was digested with 15 mL concentrated mixture of HNO_3 - $HClO_4$ - H_2O_2 (87:13:10, v/v/v) (Chang *et al.*, 2014). Zn, Ni, Fe, Cu, Pb, Cr, and Cd in the digested plant samples were determined with Atomic Absorption Spectrophotometer. Triplicate determination was performed for all the samples, and field blank determination was done after every 10 sample determinations.

DATA ANALYSES

To assess the soil pollution status, enrichment factor (EF) was calculated based on Rajmohan, *et al*., (2014) using equation 1

$$EF = \frac{(M/Fe)\text{Sample}}{(M/Fe)\text{Background}} \quad (1)$$

Where M stands for the concentration of target heavy metal and Fe was used as the normalising factor. Fe was used due to its abundance in Nigeria soil (Olowu *et al.*, 2010. Other metals that could have been considered as normalising factors are Mn and Al (Nowrouzi and Pourkhabbaz, 2014). The background sample was taken from the shale data in Turekian and Wedepohl (1961) and the metallic enrichment factors were correlated to the enrichment factor values in Table 1.

TABLE 1: ENRICHMENT FACTORS

Enrichment factor	Description
< 1	No enrichment
1-3	Minor enrichment
3-5	Moderate enrichment
5-10	Moderately severe enrichment
10-25	Severe enrichment
25-50	Very severe enrichment
> 50	Extremely severe enrichment

Bio-accumulation factor (BCF) has been commonly used to assess the metal uptake capacity/ accumulation potential of metals in plants (Zou *et al.*, 2006; García *et al.*, 2009, Wang *et al.*, 2012). The BCF of the metal in plant sample was determined using equation 2.

$$BCF = \frac{\text{Cp}}{\text{Cs}} \quad (2)$$

Where Cp represents the concentration metals of interest in the plants shoot (mg/Kg, dry weight) and Cs represents the corresponding concentration of the metals in soil (mg/Kg).

Statistical Analyses

The mean, standard deviation, range and correlation factors were determined with Microsoft excel 2007 software. Box plots, one-way ANOVA and PCA were performed with R-studio (version 3.5.2). Pearson correlation was considered significant at $p < 0.05$ and $p < 0.01$ (two-tailed).

RESULTS AND DISCUSSION

Physico-chemical properties of soil

The average pH level of the soil samples was within the range of mildly acidic to slightly alkaline (5.8 -7.7) (Table 2). Isheri-Oshun soil samples were the most alkaline (7.32), while Baruwa pipeline soil samples were some of the most acidic (6.02). The pH of Iyana-Iba (5.80 – 7.50) and Baruwa pipeline (5.50 – 7.30) samples were more closely related while Isheri-Osun (7.10 – 7.50) and Idi-araba (6.20 – 6.80) soil samples were all slightly alkaline and slightly acidic respectively. The soil samples cation exchange capacity (CEC) range was wide in all locations. The highest range was recorded at Iyana-Iba (13.73 – 71.39 cmol kg^{-1}) (Table 2). Averagely, Iyana-Iba samples had the highest CEC (40.97) while Baruwa pipeline samples have the lowest CEC (28.93). The pH and the CEC values were all higher than the pH of soils (6.03) recorded in Zhou *et al.,* (2016).

TABLE 2: CHEMICAL PROPERTIES OF THE RHIZOSPHERE SOILS

Sample locations		pH	CEC cmol kg^{-1}
	Min.	5.50	22.16
Baruwa Pipeline (n=5)	Max.	7.30	36.74
	Mean±Std	6.02 ±0.73	28.93±5.52
	Min.	6.2	24.90
Idi – Araba (n=4)	Max.	6.8	64.82
	Mean±Std	6.55±0.26	39.82±19.12
	Min.	7.10	17.23
Isheri – Oshun (n=5)	Max.	7.50	56.20
	Mean±Std	7.32±0.15	34.71±16.40
	Min.	5.80	13.73
Iyana-Iba (n =7)	Max.	7.50	71.39
	Mean±Std	6.33±0.68	40.97±20.14

Heavy metal concentration in soil

The concentration of metals in the soil samples is presented in Table 3. Baruwa-pipeline samples indicated the highest average concentrations of Zn (68.91 mg/kg), Cu (19.31 mg/kg), Fe (9874.36 mg/kg), and Pb (79.59 mg/kg). Zn and Cu were both below the FAO/WHO permissible limits of 300mg/kg and 100mg/kg respectively while Pb exceeded the FAO/WHO permissible limit of 50mg/kg (FAO/WHO, 2001). Isheri-Oshun indicated the highest average concentration of Ni (15.18 mg/kg) while Iyana-Iba indicated the highest concentration of Cr (58.21 mg/kg) and Cd (1.62 mg/kg). These were all below the FAO/WHO permissible limits of 50 mg/kg for Ni (FAO/WHO, 2001), 100 mg/kg for Cr (Ministry of Environment, Finland, 2007) and 3 mg/kg for Cd (WHO/FAO, 2001). The lowest concentrations of Pb (41.66 mg/kg), Zn (20.34 mg/kg), Cu (9.20 mg/kg) and Cr (48.00 mg/kg) were recorded in Idi- Araba while the lowest concentration for Fe (4028.06 mg/kg) was recorded in Isheri-Oshun whereas the lowest concentration of Cd (1.40 mg/kg) and Ni (7.25 mg/kg) were recorded in Baruwa-pipeline. These were all below the FAO/WHO permissible limits of 50 mg/kg, 300 mg/kg, 100 mg/kg, 100 mg/kg, 3 mg/kg and 50 mg/kg of Pb, Zn, Cu, Cr, Cd and Ni respectively (FAO/WHO, 2001). The decreasing order of the concentrations of metals found was: Iyana-Iba (Fe > Cr > Pb > Zn > Cu > Ni > Cd), Baruwa pipeline (Fe > Pb > Zn > Cr > Cu > Ni > Cd), Isheri-Oshun (Fe > Pb > Cr > Zn > Ni > Cu > Cd); Idi-Araba (Fe > Cr > Pb > Zn > Ni > Cu > Cd). In all the samples evaluated, Cd was the least found while Fe was the most predominant. This is expected as Fe is naturally abundant in Nigeria soil (Olowu *et al.*, 2010). The values recorded for Zn (39.83 – 68.91 mg/kg), Ni (7.25 – 15.18 mg/kg), and Cd (1.40 – 1.62 mg/kg) were below FAO/WHO limits and were lower than what were reported by Olu-Owolabi *et al*., (2012) which were Zn - 123.60 mg/kg, Ni - 30.00 mg/kg and Cd - 9.50 mg/kg). The concentrations obtained for Pb (41.66 – 79.59 mg/kg) were however comparable with Pb (60.10 mg/kg) in this study which exceeds the FAO/WHO limit of 50 mg/kg, while Cr (48.00 – 58.21 mg/kg) in this study was lower than the FAO/WHO limit (FAO/WHO, 2001) but higher than the Cr (20 mg/kg) obtained in Olu-Owolabi et al., (2012). Acording to Adeyi and Babalola (2017), the concentration of Pb in soil in residential areas of Lagos can averagely range from 5.94 to 90.5 mg/kg and Cd from 0.26 to 0.95 mg/kg. The concentrations of Fe (18328 – 37980 mg/kg), Cu (146 – 165 mg/kg), Zn (126 – 164 mg/kg), Pb (116 – 148 mg/kg) recorded in Urga area of Korba, India (Ramteke *et al.,* 2016) are higher than the reports of this study while Cr (34 – 72 mg/kg) and Cd (1.11 -1.39 mg/kg) are similar to what were obtained in this study (table 3). Although the condition and the pollution levels vary from one city to the other, the Cd and Fe reported in this study were comparable to Cd (0.80 – 2.40 mg/kg) and Fe (1120 -1945 mg/kg) reported on some farm yards in Lagos soil (Anyakora *et al.,* 2013). The Pb, Cr and Cu values are higher compare to the report in this study. These implies that the condition and pollution levels varies from one location to the other.

Considering the enrichment factors (Fig. 1), Pb and Cd are extremely enriched in soil samples from all the location samples. The highest average enrichment factors of Pb (103.77) and Cd (166.16) were recorded at Baruwa pipeline whereas the lowest enrichment factors, Pb (44.84) and Cd (67.88), were recorded at Iyana-Iba, indicating that the sample locations were severely polluted with Pb and Cd. The high concentration of Pb and Cd in the samples could be related to domestic impacts of the residential areas around the farmlands, as a result of outflow of water from the drainage system. Adeyi and Babalola (2017) had initially reported high concentrations of Pb in Lagos soil and linked the source to paint in residential areas.

According to ATSDR (2007), Pb entered the environment through alloys used for pipes and solder storage batteries, pigments in paints and dyes and combustion of lead petrol. Although the amount of lead used might have reduced over the years, lead sticks strongly to soil particles and remain in the upper layer, when it falls on soil. In most studies on heavy metals as related to Nigeria soil and waters, the concentration of Zn was always found higher than Pb (Adeniyi *et al.,* 2008; Chinwe *et al.*, 2010; Sulaiman *et al*., 2018) except when there is clear cut lead pollution (Ogundiran and Osibanjo, 2008; Adeyi and Torto, 2014). The observation of Pb concentrations above Zn concentrations could indicate activities enriching Pb in the environment. The Baruwa pipeline, Isheri-Oshun and Idi - Araba farm samples also indicated high chromium enrichment factor in decreasing order as listed. Similar to the observation of Pb and Cd, Baruwa samples indicated the highest Cr enrichment. Zn, Ni, Fe, and Cu were not found enriched in any of the locations. From the enrichment trend, the locations could be arranged in the decreasing order; Baruwa pipeline > Idi-Araba > Isheri-Oshun > Iyana-Iba. This pattern was expected except for Isheri-Oshun and Iyana-Iba. Isheri-Oshun samples being collected from a less populated area, was expected to have a lesser Pb concentrations than Iyana-Iba. The enrichment values reported in this study are far lower than that's of Emurotu and Onianwa (2017) during the bioaccumulation assessment of heavy metals in soil and selected food crops cultivated in Kogi State, Nigeria. This is obvious as Kogi is relatively less industrialised than Lagos State and there can be assumptions that the rhizosphere soils in Kogi were less polluted.

The Pearson correlation between the physico-chemical parameters and heavy metals in soil

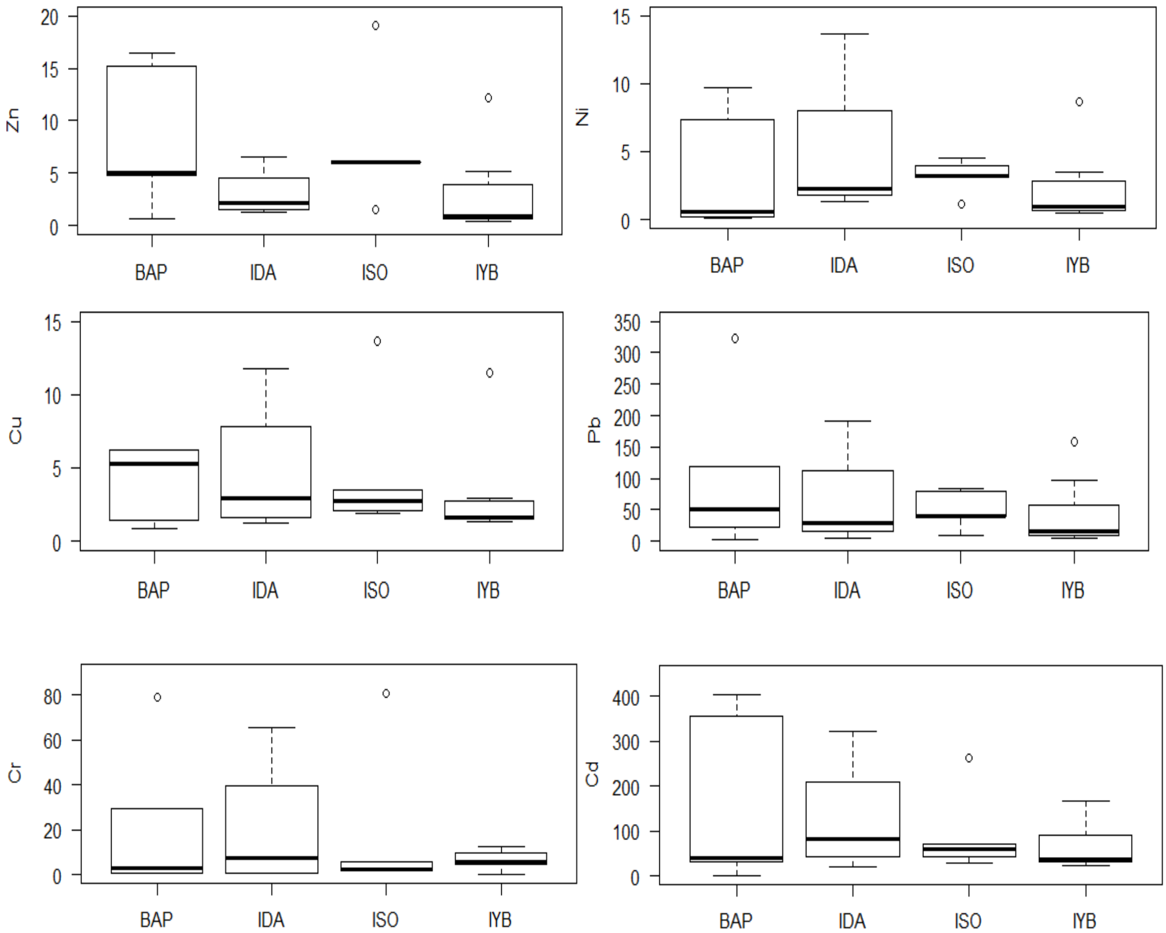
Table 4 shows the relationships between the physico-chemical properties and heavy metal in the soil. Soil pH correlated positively with: Zn ($r = 0.945$, $p > 0.05$) and Pb ($r = 0.820$, $p < 0.05$) in Baruwa-pipeline; Pb ($r = 0.644$, $p < 0.05$), Cr ($r = 0.644$, $p > 0.05$) and Cd ($r = 0.904$, $p < 0.01$) in Idi-Araba; Cu ($r = 0.609$, $p > 0.05$) in Isheri-Oshun; and Zn ($r = 0.728$, $r > 0.05$), Fe ($r = 0.623$, $r < 0.01$) and Cu ($r = 0.624$, $r < 0.05$) in Iyana-Iba. The cation exchange capacity (CEC) correlation is positive with: Zn ($r = 0.854$, $p > 0.05$), Ni ($r = 0.559$, $p > 0.05$), Fe ($r = 0.942$, $p > 0.05$) in Idi-Araba; Zn ($r = 0.494$, $p > 0.05$), Ni ($r = 0.728$, $p > 0.05$), and Pb ($r = 0.861$, $p > 0.05$) in Isheri-Oshun; Fe ($r = 0.567$, $p < 0.01$) and Cr ($r = 0.528$, $p > 0.05$) in Iyana-Iba. No correlation was observed in Baruwa-pipeline. The pH of the study sites ranged from 5.50 at Baruwa Pipeline to 7.50 at Isheri-Oshun and Iyana-Iba while the cation exchange capacity (CEC) ranged from 13.73 at Isheri-Oshun to 71.39 at Iyana-Iba. Soil pH and CEC can influence the bio-availability of heavy metals for plants uptake (Fijałkowski *et al.*, 2012. Generally, metal sorption increases with increasing soil pH, and when pH falls to below 5, mobility is enhanced as a result of the increased proton concentration (Paulose *et al*., 2007).

The lower the pH value the more metal can be found in solution and thus more metal is mobilized. This is reflected in the positive correlation between pH and the metals as seen in this study. CEC is a dominant factor in heavy metals retention. The capacity of the soils for adsorbing heavy metals is correlated with their CEC (Harter and Naidu 2001). The greater the CEC values, the more exchange sites on soil minerals will be available for metal retention. In solution, metal cations such as Cu, Zn, Cd, and Pb compete with more abundant soil cations such as Ca^{2+} and Mg^{2+} for both nonspecific and specific exchange sites. Chen (2012) found that the presence of Pb did significantly reduce the adsorption maximum of Cd on soils. This is in agreement with the results obtained in this study (Table 3).

TABLE 3: HEAVY METALS CONCENTRATION (MG/KG, MEAN ± STANDARD DEVIATION) IN THE FARM RHIZOSPHERE SOILS

		Concentrations (mg/Kg)						
Soil locations		**Zn**	**Ni**	**Fe**	**Cu**	**Pb**	**Cr**	**Cd**
	Min.	8.27	1.34	776.45	4.86	34.35	12.23	ND
Baruwa	Max.	195.08	10.80	33726.23	32.25	138.23	124.26	2.12
Pipeline	Mean±Std	68.91±74.62	7.25±3.97	9874.36±13698.69	19.31±11.49	79.59±45.45	50.42±42.94	1.40±0.82
	Min.	8.62	8.69	853.12	6.46	20.39	8.15	1.38
	Max.	52.38	19.18	9946.35	11.33	68.43	106.82	1.74
Idi-Araba	Mean±Std	20.34±21.39	13.97±4.83	4215.45±3974.86	9.20±2.02	41.66±22.28	48.00±48.02	1.53±0.19
	Min.	23.23	6.25	1105.76	8.26	26.31	16.47	1.15
	Max.	54.26	20.79	7586.53	19.73	83.67	170.95	1.84
Isheri– Oshun	Mean±Std	40.96±13.90	15.18±6.04	4028.06±2438.76	11.94±5.03	60.10±25.57	53.43±66.17	1.47±0.29
	Min.	3.12	3.72	1462.22	4.66	22.39	2.78	1.21
	Max.	183.45	19.11	8263.70	20.73	122.14	140.83	2.53
Iyana-Iba	Mean±Std	39.83±63.91	11.52±5.94	5429.92±2405.14	12.02±5.55	53.91±40.30	58.21±43.87	1.62±0.46

ND: NO DATA



BAP – Baruwa pipeline **IDA** – Idi-Araba **ISO** – Isherin Oshun **IYB** –Iyana Iba

FIG. 1: ENRICHMENT FACTORS OF HEAVY METALS IN THE FARM SOILS

TABLE 4: SIMPLE PEARSON CORRELATIONS MATRIX BETWEEN THE CHEMICAL PROPERTIES AND HEAVY METALS IN THE RHIZOSPHERE SOILS

Locations	Parameters	Zn	Ni	Fe	Cu	Pb	Cr	Cd
	pH	**0.945**	-0.459	-0268	0.464	**0.820***	-0.150	0.305**
BAP	MC	-0.181	-0.055	-0.963	-0.522	0.232*	0.343	**0.924****
	CEC	-0.599	0.262**	-0.103	-0.202	-0.815	-0.284	-0.031**
	pH	-0.859	-0.467	-0.970	-0.290	**0.644***	**0.869**	**0.904****
IDA	MC	**0.637**	-0.012	**0.752**	**0.510**	-0.898	-0.537	**0.508****
	CEC	**0.854**	**0.559**	**0.942**	0.263*	-0.614	-0.846	-0.894*
	pH	-0.874**	-0.440*	0.331*	**0.609**	-0.498**	0.030	0.048**
ISO	MC	**0.567****	**0.962**	0.425*	-0.573	**0.627***	-0.848	-0.350**
	CEC	0.494	**0.728**	-0.182*	-0.857*	**0.861**	-0.532	-0.161*
	pH	**0.728**	-0.351	**0.623****	**0.624***	-0.497*	-0.239*	-0.233**
IYB	MC	0.362	-205	0.266**	**0.604**	-0.621*	0.224*	-0.736**
	CEC	0.272	0.178**	**0.567****	0.226**	-0.246	**0.528**	-0.037**

BAP – Baruwa pipeline **IDA** – Idi Araba **ISO** – Isherin Oshun **IYB** –Iyana Iba

* Correlation is significant at the 0.05 level (Two-tailed)
** Correlation is significant at the 0.01 level (Two-tailed)

Principal components analysis of heavy metals in the Agricultural soil samples

Three basic factors were suggested for metal sources in the examined farmlands; natural sources, atmospheric deposition and urban storm water which could be a major link between the soil environmental activities (including canals) and the farmlands. It should be noted that urban storm water and two or more water sources could be available for water irrigation and, a metal could be sourced from two or more factors. An investigation using Principal component analysis (PCA) was carried out to link these sources to the specific metals. PCA is relevant and has been commonly applied for pollutants source identification and appropriation (Lu *et al.*, 2010; Shan *et al.*, 2013; Chang *et al.*, 2014).

Three principal components were extracted from the principal component analysis based on Eigen values ≥ 1 (Table 5). The first principal component which explained 32 % of the total variation was heavily loaded on Fe (0.555) and negatively loaded on Ni (-0.505) and Cd (- 0.583). This indicated likely similar sources of Ni and Cd different from Fe source. Iron is naturally abundant in the soil; therefore, the source could be traced to natural soil while Cd and Ni are linked to atmospheric deposition from the traffic sources, storm or irrigation water. In the second principal component which was loaded on Zn (0.620), Ni (0.454) and Cu (0.479) showed a common source for the metals, and this suggested that Ni had multiple sources. The third principal component was loaded on Pb (0.515) and Ni (0.463). This could indicate a common source for Pb and Ni. The sources of Pb may be traceable to anthropogenic activities around the cultivation site probably carried by urban water storm.

TABLE 5: PRINCIPAL COMPONENT ANALYSIS OF HEAVY METAL CONCENTRATIONS IN THE FARM SOIL

	PC1	PC2	PC3
Zn	0.147	**0.620**	0.323
Ni	**-0.505**	**0.454**	**0.463**
Fe	**0.555**	-	-
Cu	0.362	**0.479**	-
Pb	-0.349	0.228	**0.515**
Cr	-0.276	0.182	**-0.647**
Cd	**-0.583**	0.210	-
Eig. Val.	1.51	1.25	1.05
Var	32.48	22.43	15.89
Cum Var.	32.48	54.91	70.80

BAP – Baruwa pipeline **IDA** – Idi-Araba **ISO** – Isheri - Oshun **IYB** –Iyana Iba

Concentration of heavy metals in vegetable edible parts

According to Table 6, the average concentration of Zn found in the vegetable samples were lower than the (FAO/WHO, 2007) permissible limit (60.0 mg/kg) (Table 6), except *Amaranthus viridis, Celosia argentea and Talinum triangulare* samples. From the locations, only samples from Baruwa pipeline indicated higher concentration than the permissible limit. Zn was found in the sequence: *Amaranthus viridis* (86.55 mg) >*Talinum triangulare* (83.29 mg/kg) > *Celosia argentea* (66.71 mg) > *Lactusa sativa* (47.02 mg) > *Allium tricoccum* (32.17 mg/kg) > *Telfairia occidentalis* (28.16 mg) >*Corchorus olitorius* (23.61 mg/kg). In terms of locations, the average concentration was found as Baruwa pipeline (67.47 mg) > Iyana-Iba (53.99 mg/kg) > Isheri-Oshun (55.25 mg/kg) > Idi-Araba (47.39 mg/kg) (Table 7).

The average concentration of Ni was in all the samples except in few samples from *Amaranthus viridis* collected at Idi-Araba. The vegetable samples from Iyana-Iba and Baruwa-pipeline indicated the highest concentration of Ni (23.89 mg/kg and 23.26 mg/kg respectively) (Table 7). Fe was also found high in all the vegetable parts with the order being: *Lactusa sativa* (7739.19 mg/kg) > *Celosia argentea* (4567.20 mg) > *Allium tricoccum* (4378.73 mg) > *Talinum triangulare* (3850.06 mg/kg) > *Amaranthus viridis* (2881.44 mg/kg) > *Corchorus olitorius* (2685.37 mg/kg) > *Telfairia occidentalis* (2058.63 mg/kg).

Vegetable parts from Idi-Araba were found with the highest concentrations of Fe while the vegetable parts from Isheri-Oshun indicated the lowest. The copper concentration determined (40.0 mg/kg) was lower than the permissible limits proposed by the (WHO/FAO, 2007). Copper was determined in the range 9.66 to 21.80 mg/kg with the highest concentration being in *Lactusa sativa* (21.58 mg/kg) and *Allium tricoccum* samples (21.80 mg). Idi-Araba vegetable samples were found with the highest concentration (26.25 mg). Concentration of Pb was found to be higher than the permissible limits (5.0 mg/kg) in all the samples (Table 6). The average concentration of Pb was found between 14.15

to 43.05 mg/kg. The highest concentration was found in *Amaranthus viridis* (43.05 mg/kg) and vegetables from Idi-Araba were found with the highest concentration (40.72 mg/kg).

Chromium was found with concentration higher than the regulatory standard (2.3 mg/kg) in all the samples. The concentration is in the order: *Amaranthus viridis* (50.95 mg/kg) > *Celosia argentea* (38.69 mg/kg) > *Allium tricoccum* (32.65 mg/kg) > *Telfairia occidentalis* (27.84 mg/kg) > *Lactusa sativa* (23.97 mg/kg) > *Corchorus olitorius* (21.56 mg/kg) > *Talinum triangulare* (16.43 mg/kg). The highest concentration of Cr was found in vegetable samples from Isheri-Oshun (43.07 mg/kg).

Cadmium was found with the lowest concentrations among all the metals (Table 6) with a range of 1.58 to 2.51 mg/kg. Cadmium was found higher than the permissible safety limit (0.2 mg/kg) in all the samples. The highest vegetable concentration was found in vegetables obtained from Baruwa Pipeline (2.39 mg/kg).

This study indicated that the vegetable parts obtained from the study locations were polluted with Pb, Cr and Cd. According to Volpe *et al.* (2009). Out of these metals, Cd and Pb are the most toxic elements for man. Cadmium is a toxic metal that could cause bone fragility and kidney damages. Lead affects the nervous system. Its exposure may lead to weakness in fingers, ankle and wrist, anaemia, kidney and brain damage or death. Toxicity of Cr causes stomach and small intestine irritation and ulcer, blood anaemia, and sperm damage (ATSDR, 2007; ATSDR, 2012a, 2012b). The results of these studies are generally higher than the reports on Spinach (Cd – 0.35 mg/kg, Cr – 6.63 mg/kg, Cu – 22.25 mg/kg, Fe – 968.25 mg/kg, Ni – 4.65 mg/kg, Pb – ND, Zn – 19.5 mg/kg) by Latif *et al.* (2018) on agricultural soil in Pakistan, although the climate condition and level of pollution differs.

The values of Lead in the selected plants are relatively lower than the reports of Atayese *et al.*, (2008) where heavy metals in *Amaranthus viridis* along major highways were assessed. The concentration of Cd is however within the permissible limits.

The result for *Telfairia occidentalis* in the present study is comparable to the report of Olu-Owolabi et al. (2012) for Zn (23.20 mg/kg). However, the results are higher for Ni (9.40 mg/kg), Pb (21.50 mg/kg), Cd (0.88 mg/kg), and Cr (7.55 mg/kg) but lower for Cu (22.00 mg/kg). The results are higher than the reports in Opaluwa *et al.*, (2012) for heavy metals in Roselle and spinach in samples collected around dumpsites in Nasarawa State, Nigeria. The values in this report are generally higher than the study in Lawal and Audu (2011) in Kano. The values in this study are also higher than the reports in Pb (0.004–2.361 mg/kg), Cd (0.002–2.918 mg/kg), and Cu (0.155–3.125 mg/kg) in Zhou *et al.* (2016) except Zn (1.151–54.65 mg/kg) which was within the range. Ramteke *et al.*, (2016) reported mean concentration values of Fe (2255 ± 116 mg/kg), Zn (106 ± 15 mg/kg), Cr (10 ± 3 mg/kg), Cu (36 ± 4 mg/kg), Cd (0.67± 0.11 mg/kg) and Pb (0.7 ± 0.04 mg/kg) for *Amaranthus* species obtained in India. The values reported for Fe, Zn, and Cu are within the range of the reports for *Amaranthus viridis* in this study, while Cr, Cd and Pb are lower than the values in reported in this study. The variations of results are expected since the pollutions status of vegetable plants are related to soil characteristics and pollutions.

TABLE 6: HEAVY METALS CONCENTRATION (MG KG^{-1} DW, MEAN ± STANDARD DEVIATION) IN VEGETABLES

Vegetable Species		Concentrations (mg/Kg)						
		Zn	**Ni**	**Fe**	**Cu**	**Pb**	**Cr**	**Cd**
Amaranthus viridis	Min.	45.35	ND	943.60	11.62	26.41	20.36	1.73
	Max.	110.47	25.33	4253.25	39.13	60.23	102.73	2.85
	Mean±Std	86.55±28.74	15.51±11.90	2881.44±1601.82	20.04±12.82	43.05±13.95	50.95±38.94	2.19±0.55
Celosia argentea	Min.	49.13	17.47	2373.14	14.85	15.98	17.45	1.22
	Max.	99.67	34.13	5975.59	19.66	49.73	64.25	2.28
	Mean±Std	66.71±23.23	22.73±7.67	4567.20±1718.68	17.08±2.53	37.45±24.33	38.69±19.58	1.58±0.50
Corchorus olitorius	Min.	17.14	22.56	1292.33	8.48	30.27	11.43	1.43
	Max.	35.45	29.63	3725.43	12.86	46.84	31.87	3.46
	Mean±Std	23.61±10.27	25.62±3.63	2685.37±1254.37	9.66±2.80	37.32±8.56	21.56±10.22	2.51±1.02
Lactusa sativa	Min.	41.22	20.36	6818.65	15.13	21.46	20.36	1.68
	Max.	57.28	25.55	9155.45	27.77	39.14	27.22	1.72
	Mean±Std	47.02±8.91	22.88±2.60	7739.19±1249.62	21.58±6.32	30.45±8.84	23.97±3.44	1.69±0.03
Telfairia occidentalis	Min.	19.69	6.15	1874.28	4.37	16.63	24.73	1.44
	Max.	44.18	21.67	2374.36	17.45	60.13	32.53	2.15
	Mean±Std	28.16±13.89	16.33±8.82	2058.63±274.71	11.70±6.68	42.70±23.00	27.84±4.13	1.91±0.41
Allium tricoccum	Min.	29.24	20.75	2285.39	19.25	10.87	20.72	1.13
	Max.	35.15	25.19	6528.18	25.17	16.11	44.68	2.73
	Mean±Std	32.17±2.96	23.36±2.32	4378.73±2121.95	21.80±3.04	14.15±2.86	32.65±11.98	1.90±0.80
Tallium triangulare	Min.	68.97	20.23	2222.84	13.24	16.23	9.12	1.62
	Max.	101.74	24.69	2653.63	19.53	40.32	30.78	2.35
	Mean±Std	83.29±16.77	22.09±2.32	3850.06±2454.82	16.52±3.15	27.89±12.06	16.43±12.43	2.06±0.39
WHO/FAO (2007) Standard		60.0	-	-	40.0	5.0	2.3	0.2

TABLE 7: HEAVY METALS CONCENTRATION (MG/KG, MEAN ± STANDARD DEVIATION) OF VEGETABLE IN FARM SOILS

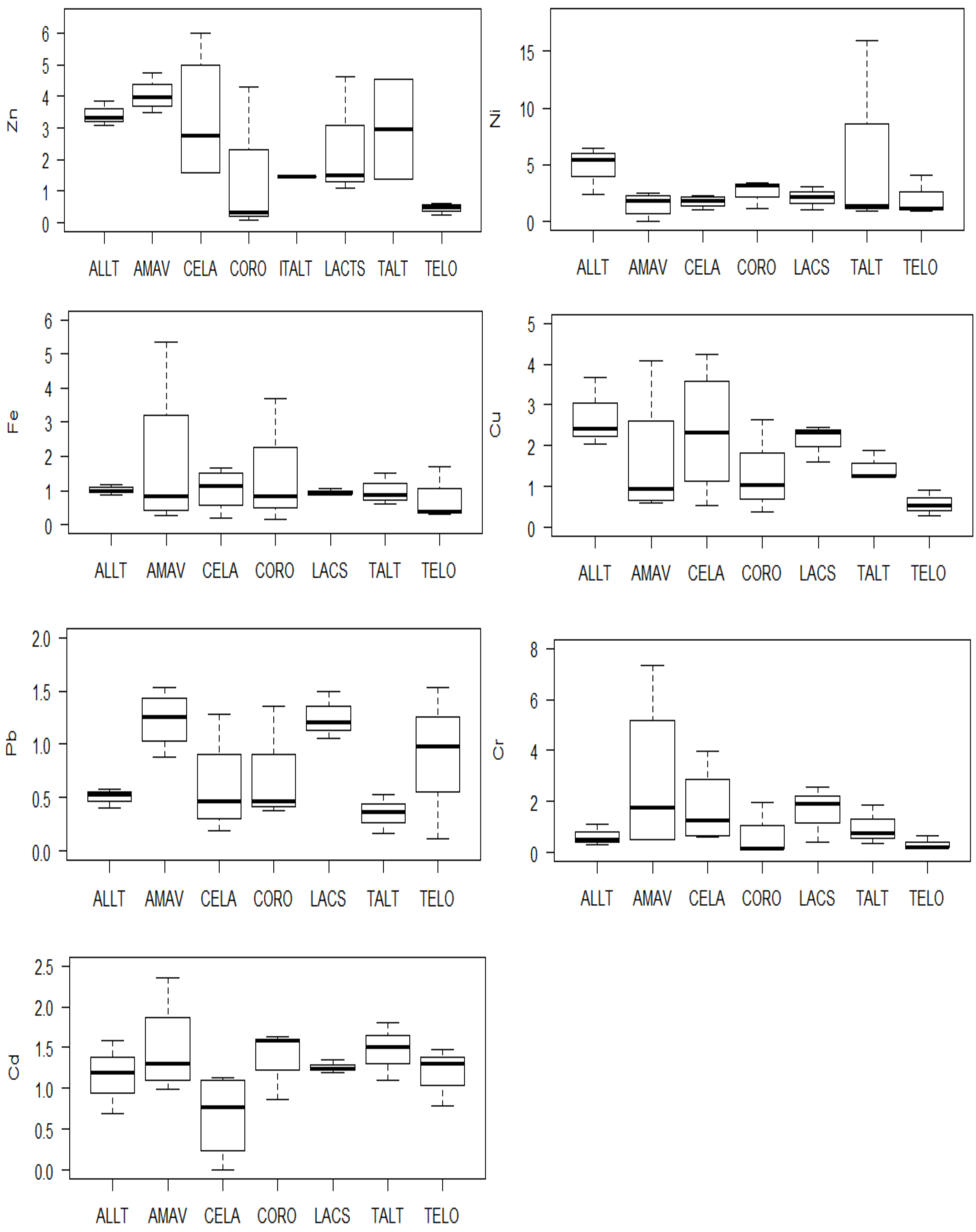
Soil locations		Concentrations (mg/Kg)						
		Zn	**Ni**	**Fe**	**Cu**	**Pb**	**Cr**	**Cd**
Iyana-Iba	Min.	17.14	12.38	1292.33	7.65	14.87	11.43	1.24
	Max.	100.64	34.13	6528.18	25.17	51.34	44.68	2.85
	Mean±Std	53.99±35.97	23.89±6.41	3635.60±2229.24	16.34±5.64	32.57±14.80	25.69±13.52	2.06±0.63
Baruwa Pipeline	Min.	35.45	19.85	1927.25	12.86	16.63	9.38	1.62
	Max.	101.74	29.63	6673.71	17.45	46.84	64.25	3.56
	Mean±Std	67.47±10.92	23.26±3.92	4350.82±1979.69	14.81±1.85	30.83±14.44	28.26±20.97	2.39±0.67
Isheri–Oshun	Min.	18.24	6.15	1874.28	4.37	15.98	17.45	1.22
	Max.	110.47	25.33	4253.25	16.79	60.13	102.73	2.65
	Mean±Std	55.25±39.46	18.35±7.41	2975.95±984.14	11.22±4.97	38.32±15.77	43.07±33.92	1.86±0.58
Idi-Araba	Min.	35.15	ND	943.60	18.84	15.47	20.72	1.13
	Max.	57.28	20.75	9155.45	39.13	65.72	59.15	1.73
	Mean±Std	47.39±9.50	15.15±10.11	4570.34±3703.93	26.25±9.52	40.72±25.91	34.12±17.37	1.53±0.27

Bio-Concentration Factors (BCF) of heavy metals in vegetables

The uptake of metals by plants is usually identified through BCF and plants with values greater than or equal to one are considered as accumulators (Pollard *et al.*, 2002, Radulescu *et al.*, 2013). The BCF of this study are generally higher Zn (0.09 – 6.01), Ni (0.97 – 15.93), Fe (0.17 – 5.33), Cu (0.30 - 4.25), Pb (0.12 – 1.53), Cr (0.15 – 7.32) and Cd (0.49 – 2.36) when compared with similar studies (Olayinka *et al.*, 2011; Radulescu *et al.*, 2013). Olu-Owolabi *et al.* (2012) reported lower concentrations of metals in vegetables than in the soil. The BCF report in Atayese *et al*. (2008), of Pb (2.54 -2.57) and Cd (3.01 - 3.11), for vegetables taken at a distance of 20m from the road are however higher than the report of this study. The variation of these results could be attributed to the possibility of multiple sources of metals to the vegetables, more likely, sources from atmospheric deposition of contaminated irrigation water or storm water. This concern had been previously raised by Atayese *et al.*, (2008) and Osundiya *et al.*, (2014).

For source identification, 3 principal components were extracted from the principal component analysis using Eigen value ≥ 1 (Table 8). The first principal component accounted for 31.11% of the total variation, and this component loaded heavily on Zn (0.577), Fe (0.517) and Cu (0.553). This suggests a similar source for Zn, Fe and Cu. From Figure 1, Cu, Fe and Zn are also poorly enriched in the soil samples. Also, from Figure 2, the three metals indicated very high BCF. The major source of Zn, Fe and Cu therefore could be attributed to atmospheric deposition or irrigation water, not from soil accumulation. The second principal component explained 19.17 % of the total variation and heavily loaded on Cr (0.644) and Pb (0.484). Barcelo and Poschenrieder (1997), Zou *et al.*, (2006) and Wang *et al.*, (2012) had already indicated that plants have a low capacity to absorb and translocate Cr. With the high Cr BCF values, the source could be other than soil, and foliar absorption through atmospheric deposition is suggested. According to Popoola *et al.* (2012), Cr is more related to industrial activities than automobile sources in street dust. From this, it could be suggested that the Cr in the vegetables came from irrigation water or water storm through foliar absorption. The third component indicated 14.96 % of the total variation. The loading was placed on Pb and Cd, these metals are well enriched in the soil samples. Cd has high soil to plant accumulation index.

Chang *et al.* (2014) and Zhou *et al.* (2016) had shown that Cd has a high potential of being accumulated into vegetables' tissues from soil. They reported maximum values of 4.26 and 3.10 respectively which are higher than the values in this study. Also, the report in Bi *et al.* (2018) is comparable to the study. With this information, the concentration of Cd and Pb in the vegetables in this study can be attributed to soil accumulation. The agricultural soils are also likely affected by environmental influences including urban storm water, irrigation water and atmospheric deposition. The BCF values in this study were higher than the reports in Towolawi *et al.,* 2017 (Cu - 0.01 to 0.04 mg/kg and Zn - 0.55 to 2.20 mg/kg) for *Amaranthus viridis* grown on soil amended with sewage sludge. Except Cd, the values in this study were higher than the reports of Chang *et al*. (2014) and Zhou *et al.* (2016).



AMAV - *Amaranthus viridis* **CELA -** *Celosia argentea* **CORO -** *Corchorus olitorius* **LACS -** *Lactusa sativa*
TELO - *Telfairia occidentalis* **ALLT -** *Allium tricoccum* **TALT -** *Talinum triangulare*

FIG. 2: BIO-CONCENTRATION FACTORS OF HEAVY METALS IN THE VEGETABLES

TABLE 8: PRINCIPAL COMPONENT ANALYSIS OF BIO-CONCENTRATION FACTORS IN VEGETABLES

	PC1	PC2	PC3
Zn	**0.577**	0.242	-
Ni	0.150	**-0.404**	0.220
Fe	**0.517**	-0.169	0.142
Cu	**0.553**	-	-
Pb	-0.196	**0.484**	**0.531**
Cr	0.167	**0.644**	0.125
Cd	-	-0.313	**0.791**
Eig. Val.	1.48	1.16	1.02
Var	41.11	19.17	14.96
Cum Var.	41.11	60.28	75.24

CONCLUSION

This study indicated that the soil in the studied locations are polluted with Cd, Pb, Zn, and Cr. The sources of this metal pollution may be traceable to urban storm water, water irrigation and atmospheric deposition. The study also indicated that the vegetables grown in these areas could be polluted with Ni, Cr, Cd and Pb. These metals are alluded as few of the foremost harmful metals. The vegetables therefore, could pose serious risk to the public. It may however mean that the site in the study locations is not suitable for agricultural purpose especially during the rainy season when this study was taken. There is need therefore for further study in the dry season. It is suggested that sites used for agricultural purpose within big cities should be well monitored; the farmers could be relocated to uncontaminated land in the case of contaminated sites.

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