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## Assessment of Heavy Metals in Soil and Vegetables Grown around some Automobile Workshops in Federal Capital Territory Abuja, Nigeria

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**Abstract** This study aimed at assessing the concentrations of Cd, Cr, Cu, Fe, Pb and Zn in soil and vegetables grown around five (5) automobile workshops in the Federal Capital Territory of Nigeria. Soil and vegetable samples were collected between 2016 and 2017 in rainy and dry seasons. Heavy metals concentrations in soil and vegetables were quantified using Atomic Absorption Spectrophotometer. Transfer factors (TF) from soil to vegetables were calculated. In dry season, the concentration of heavy metals (mg/kg) in soil samples ranged from  $0.29 \pm 0.00$  -  $0.58 \pm 0.00$  for Cd, Cr:  $1.45 \pm 0.00$  -  $4.81 \pm 0.02$ , Cu:  $0.76 \pm 0.00$  -  $2.96 \pm 0.00$ , Fe:  $651.43 \pm 0.01$  -  $682.61 \pm 0.02$ , Pb:  $2.81 \pm 0.00$  -  $10.94 \pm 0.00$  and Zn:  $11.93 \pm 0.00$  -  $35.36 \pm 0.00$ . However in wet season, the levels ranged from  $0.07 \pm 0.00$  -  $0.29 \pm 0.00$  for Cd, Cr:  $1.06 \pm 0.00$  -  $1.45 \pm 0.00$ , Cu:  $0.35 \pm 0.00$  -  $1.68 \pm 0.00$ , Fe:  $534.41 \pm 0.00$  -  $549.28 \pm 0.01$ , Pb:  $2.34 \pm 0.00$  -  $5.00 \pm 0.00$  and Zn:  $6.19 \pm 0.01$  -  $32.06 \pm 0.00$ . Iron had the highest level of concentration while cadmium recorded the lowest in soil and vegetable samples. Heavy metal concentrations were higher in dry season than in wet season and the concentrations were more in soil than in vegetables. The levels of heavy metals were within WHO permissible limits for soil, while zinc, cadmium and lead were above WHO/FAO permissible limits in vegetables. Regular consumption of these vegetables may result to health problems associated with zinc, cadmium and lead.

**Keywords** Assessment, Heavy metals, Soil, Vegetables, Automobile Workshop

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### 1. Introduction

Soil is a complex mixture of organic and inorganic matter, with different components that determine its physical, chemical and biological properties. Soil is a major reservoir for contaminants as it is capable of binding various chemicals, these chemicals can occur in different forms in soil and different forces keep them bond to soil particles [1]. The properties of the soil may change due to climate change, but mostly due to anthropogenic impact.

A vegetable is any edible part of plant that is consumed by humans as food or part of a savoury meal [2]. They are green and leafy-like in appearance bearing edible stems or leaves and roots of plants [3]. Vegetables can be eaten, either raw or cooked and play an important role in human nutrition, being mostly low in fat and carbohydrates, but high in vitamins, minerals and dietary fibre, vegetables also act as buffering agents for acid substance obtained during the digestion process [4]. Phytochemicals found in vegetables have anti-inflammatory, enzyme inhibiting and bioactive features capable of fighting the activities of the oxidants [5].

Heavy metals are chemical elements having atomic number more than 20 with density greater than  $5\text{g/cm}^3$  found in soils, rocks and freshwater ecosystems [6-7]. They constitute heterogeneous group of elements which vary widely in their chemical properties and biological functions. They are non-biodegradable, having long biological half-lives,



difficult to eliminate naturally from the environment and high potentials for accumulation in different body organs leading to unwanted side effects [8].

One of the major sources of increase in heavy metals concentration in the soil ecosystem in Nigeria, is due to auto mechanic activities [9]. Karu, Nyanya, Kugbo, Apo and Lugbe areas in Federal Capital Territory (F.C.T) have experienced increase in the number of auto-mobile workshops as a result of increase in population thereby having their shares in heavy metal contamination. Heavy metals associated with the activities in automobile workshops such as fluid leakage, component wear, engine oils and corrosion of metals, painting of vehicles and tyres vulcanizing are washed into soil which may contribute to high levels of these metals in soil causing pollution. Vegetables contain both essential and toxic elements over a wide range of concentrations [10] therefore excessive heavy metals in vegetables pose a direct threat to human health.

## 2. Materials and Methods

### 2.1. Study Area

Five different automobile workshops in F.C.T Abuja were selected for this study. F.C.T, Abuja lies on the geographical coordinates of  $9^{\circ} 10' 32''\text{N}$ ,  $7^{\circ} 10' 50''\text{E}$ , it is the capital of Nigeria and shares boundaries with Kogi State, Niger State and Nasarawa State. The sampling locations were at Karu, Kugbo Nyanya, Apo and Lugbe represented by stations 1 – 5 respectively (Figure 1). All the stations have typical characteristics of automobile work sites, such as patches of waste engine oil on the ground, scrap metals, discarded engine oil containers and paint cans, among others. The control station is an uncontaminated site with no mechanic activity carried out on the soil of the land before.

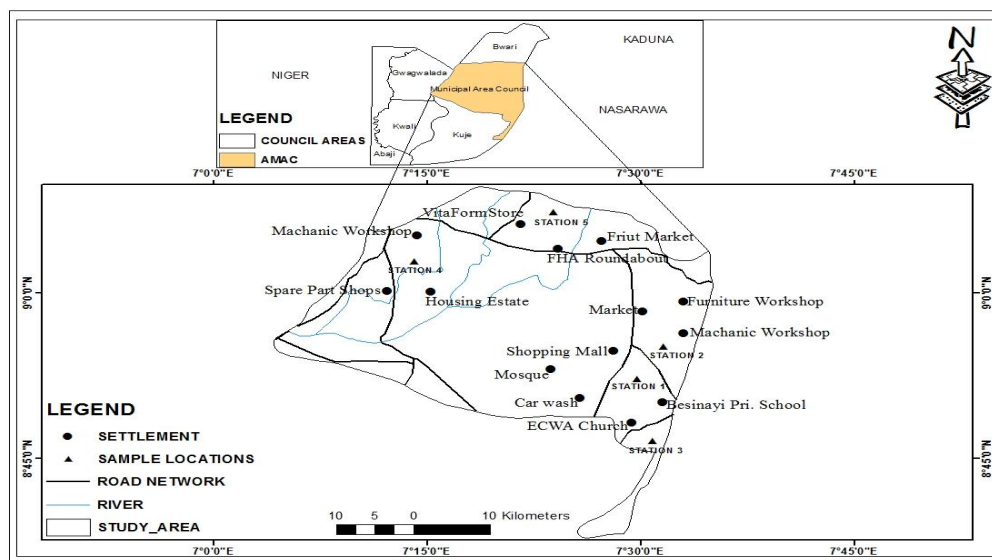


Figure 1: Map of FCT Abuja showing the study area

### 2.2. Sample Collections

Soil samples (0-10cm) were collected from the five different sites using a hand auger. Collection of the soil samples was done at twelve different points of a particular location of the sites and transferred into polyethylene bags with tight plastic clips, labelled properly and then transported to the laboratory. The subsamples were well mixed together to create a single composite sample for each of the sites and then air dried for two (2) weeks in the laboratory. These samples were then crushed and sieved through a 2mm mesh sieve to obtain fine particles and kept for acid digestion. The vegetables, Green (*Amaranthus hybridus*) and “Ewedu” (*Corchorous olitorius*) were obtained from the five sites. They were washed with water to eliminate dirt, and then air dried. The dry vegetable samples were homogenized by grinding using a kitchen grinder, sieved to 2 mm and stored in polyethylene bags with proper labelling and kept for acid digestion.



### 2.3. Sample Digestion

Soil sample (1.00 g) was weighed into a 250 cm<sup>3</sup> beaker for digestion and 10 cm<sup>3</sup> of concentrated HNO<sub>3</sub> added, then heated at 95 °C. This was refluxed after cooling, with repeated addition of HNO<sub>3</sub> until no brown fumes were given off by the sample. The volume of the solution was allowed to reduce to 5 cm<sup>3</sup> by evaporation. 10 cm<sup>3</sup> H<sub>2</sub>O<sub>2</sub> was added slowly without allowing any losses after cooling the mixture. 10 cm<sup>3</sup> of HCl was added to the mixture and refluxed at 95 °C for 15 minutes. The digest obtained was filtered using Whatman No. 41 filter paper. The filtrate was diluted, made up to 100 cm<sup>3</sup> volume in a volumetric flask and stored for analyses [11].

Sieved vegetable sample (1.0 g) was weighed into 100 cm<sup>3</sup> beaker. A mixture of 7 cm<sup>3</sup> concentrated trioxonitrate (V) acid and 4 cm<sup>3</sup> of perchloric acid was added and this was digested at low heat using hot plate until near dryness. The digest was then allowed to cool, filtered into 100 cm<sup>3</sup> standard flask using filter paper and made up to mark with deionized water [12]. This was done in three replicate for each vegetable.

### 2.4. Determination of Physicochemical Parameters of the Soil

pH: Ground and sieved soil sample (10.00 g) was weighed and transferred into a beaker, 10 cm<sup>3</sup> of deionised water was added and the mixture was stirred to obtain slurry. The mixture was allowed to stand for an hour, stirred at every 10 to 15 minutes. A calibrated pH meter with glass-calomel electrode was used for the pH measurement. Prior to the pH determination, the prepared standard buffer solutions were used for the pH calibration. The pH meter electrode was thoroughly rinsed with deionised water after immersing into each of the soil solution [13].

Cation exchange capacity: Soil sample (25.0 g) was weighed into a 500 cm<sup>3</sup> Erlenmeyer flask and 125 cm<sup>3</sup> of 1 mole dm<sup>-3</sup> NH<sub>4</sub>OAc was added and mixed thoroughly, then allowed to stand overnight. A 5.5 cm<sup>3</sup> Buchner funnel was fitted with retentive filter paper which was moisten and light suctioned, and the soil transferred. The soil was gently washed four times with 25cm<sup>3</sup> additions of the NH<sub>4</sub>OAc, allowing each addition to filter through but not allowing the soil to crack or dry. Suction was applied only to ensure slow filtering. The leachate was discarded. The soil was further washed with eight separate additions of 95% ethanol to remove excess saturating solution. The adsorbed NH<sub>4</sub> was extracted by leaching the soil with eight separate 25cm<sup>3</sup> additions of 1 mole dm<sup>-3</sup> KCl. The soil was discarded, and the leachate transferred to a 250 cm<sup>3</sup> volumetric flask. Then the volume was diluted with additional KCl.

The concentration of NH<sub>4</sub>-N in the KCl extract was determined by colorimetry. Also NH<sub>4</sub>-N was determined in the original KCl extracting solution (blank) to adjust for possible NH<sub>4</sub>-N contamination in this reagent [14].

Calculations:

$$\text{CEC (cmolc/kg)} = \frac{(\text{NH}_4\text{-N in extract} - \text{NH}_4\text{-N in blank})}{14} \quad (2.1)$$

Where NH<sub>4</sub>-N is reported in mg N/L

$$\text{CEC (cmolc/kg)} = \frac{(\text{NH}_4\text{-N in extract} - \text{NH}_4\text{-N in blank})}{18} \quad (2.2)$$

Where NH<sub>4</sub>-N is reported in mg NH<sub>4</sub>/L

Organic Matter (OM): Organic Matter was determined using Walkley-Black Method. Dry soil sample (1.00 g) was weighed and transferred into a 500 cm<sup>3</sup> Erlenmeyer flask, 10 cm<sup>3</sup> of 0.167 moles dm<sup>-3</sup> potassium dichromate (K<sub>2</sub>Cr<sub>2</sub>O<sub>7</sub>) solution was added using pipette followed by the addition of 20 cm<sup>3</sup> of concentrated H<sub>2</sub>SO<sub>4</sub> using a dispenser and the mixture was swirled gently to mix. The mixture was allowed to stand for 30 minutes and diluted with 200 cm<sup>3</sup> of deionised water. Phosphoric acid (10 cm<sup>3</sup>) was added followed by 0.2 g sodium fluoride (NaF). (The H<sub>3</sub>PO<sub>4</sub> and NaF were added to complex Fe<sup>3+</sup> which would interfere with the titration end point). This was followed by the addition of 10 drops ferroin indicator. The mixture was titrated with 0.5 moles dm<sup>-3</sup> Fe<sup>2+</sup> solution, the colour of the solution at the beginning was yellow-orange to dark green, while the colour changed to wine red at the end point. A blank was prepared and titrated in the same manner but without the soil [15].

$$\% \text{ Organic Matter} = 10[1 - (S \div B)] \times 0.67 \quad (2.3)$$



Where S is sample titration, B is blank titration, 10 is conversion factor for units. 0.67 is a factor derived from the conversion of % organic carbon to % organic matter.

Soil Salinity: Soil salinity was determined weighing soil sample (20 g) into a 250cm<sup>3</sup> beaker. 20 cm<sup>3</sup> of deionized water was added to the beaker and stirred thoroughly with glass rod for about 1 hour until well mixed, the suspension was allowed to settle. The EC of the supernatant was measured at 25<sup>0</sup>C with a conductivity meter. The conductivity meter probe was properly rinsed with deionized water before and after reading [16].

### 2.5. Heavy Metals Transfer Factor (TF)

Transfer factor is one of the key components of human exposure to metals through the food chain [17]. Transfer factor of the heavy metals from soil to vegetables was calculated as the ratio between the concentrations of heavy metals in vegetables and their respective concentration in soil.

$$TF = \frac{[\text{vegetable}]}{[\text{soil}]} \quad (2.4)$$

### 2.5. Quantification of Heavy Metals in the Samples

Heavy metal concentrations of soil and vegetable samples were determined in triplicates using an Atomic Absorption Spectrophotometer, (ASS-6800 SHIMADZU JAPAN).

## 3. Results and Discussion

### 3.1. Physicochemical Parameters of Soil Samples

Physicochemical parameters of soil were determined in dry and wet season (Table 1) the values of the pH of soils in the vicinity of automobile workshops ranged from 5.10 to 6.00 in wet season while that of control is 7.05. In dry season the values ranged from 5.00 to 5.60 with the control site having 6.90. The electrical conductivity (EC) of the soil ranged from 49.20 to 75.12  $\mu\text{S}/\text{cm}$  in wet season with Apo, Kugbo and Karu soils having values relatively higher than that of Lugbe and Nyanya, the control soil had lower values compared to the study areas. In dry season, the values ranged from 51.00 to 76.56  $\mu\text{S}/\text{cm}$ . Organic matter of the soil samples ranged from 4.90 to 6.50 %, in the wet season, with Kugbo soil having the highest value followed by Apo and Karu. The values ranged from 2.89 to 5.96 % in the dry season. The control samples had the lowest values in both seasons. Cation exchange capacity (CEC) values ranged from 8.40 to 9.50  $\text{cmol}/\text{kg}$  in the dry season, while it ranged from 7.08 to 7.92  $\text{cmol}/\text{kg}$  in the wet season.

**Table 1:** Physicochemical Parameters of Soil Samples

Sampling site	Season	Ph	EC ( $\mu\text{S}/\text{cm}$ )	OM%	CEC ( $\text{cmol}/\text{kg}$ )
Karu	wet	5.60 $\pm$ 0.05	70.00 $\pm$ 0.08	6.10 $\pm$ 0.52	7.82 $\pm$ 0.03
	dry	5.40 $\pm$ 0.06	68.14 $\pm$ 0.06	4.67 $\pm$ 0.42	8.58 $\pm$ 0.06
Kugbo	wet	5.12 $\pm$ 0.04	71.10 $\pm$ 0.06	6.50 $\pm$ 0.58	7.80 $\pm$ 0.05
	dry	5.00 $\pm$ 0.06	71.59 $\pm$ 0.06	5.96 $\pm$ 0.51	8.90 $\pm$ 0.06
Nyanya	wet	6.00 $\pm$ 0.03	49.20 $\pm$ 0.07	4.92 $\pm$ 0.58	7.92 $\pm$ 0.05
	dry	5.60 $\pm$ 0.05	51.00 $\pm$ 0.05	3.13 $\pm$ 0.23	9.50 $\pm$ 0.06
Apo	wet	5.10 $\pm$ 0.04	75.12 $\pm$ 0.06	6.11 $\pm$ 0.30	7.47 $\pm$ 0.05
	dry	5.00 $\pm$ 0.06	76.56 $\pm$ 0.07	4.10 $\pm$ 0.56	8.40 $\pm$ 0.06
Lugbe	wet	5.70 $\pm$ 0.04	64.11 $\pm$ 0.07	4.90 $\pm$ 0.54	7.08 $\pm$ 0.06
	dry	5.20 $\pm$ 0.06	66.98 $\pm$ 0.04	2.89 $\pm$ 0.40	9.02 $\pm$ 0.05
Control	wet	7.05 $\pm$ 0.05	29.10 $\pm$ 0.06	1.95 $\pm$ 0.58	7.30 $\pm$ 0.05
	dry	6.90 $\pm$ 0.06	28.57 $\pm$ 0.06	1.80 $\pm$ 0.46	9.34 $\pm$ 0.05

EC = Electrical conductivity, CEC = Cation exchange capacity, OM = Organic matter

The pH of the soils from Karu, Kugbo, Apo and Lugbe sites were acidic in dry season that of Nyanya site was slightly acidic in wet season while the control site is neutral in wet and dry season. Soil pH was more acidic in dry season than in wet season, this may be as a result of rainfall that dilutes the soil solution leading to pH increase. At



low pH, metals are more soluble in the soil solution, and more bioavailable to plants. Therefore, toxicity problems are more associated with acidic soils than in alkaline soils. The pH of the soil samples were in the same range as the values reported for seasonal variations in heavy metal concentrations in soil and some selected crops at a landfill [18], lower than the 6.3 to 7.1 reported for seasonal variations of heavy metals concentration in abattoir dumping site soil [19].

Cation exchange capacities of the soil samples values in the dry season were higher than that of the wet season. CEC can regulate the mobility of metals in soils and increases as pH increases. The values obtained were slightly higher than that reported for the evaluation of heavy metals in soils around automobile workshop clusters in Gboko and Makurdi [20], however, it is similar with some of the values reported on the impact of Nigerian flood disaster on the soil quality of farmlands [21].

Organic matter contents were higher in the study areas than that of the control which may be due to the presence of more waste from the activities carried out around the sites, there was slight difference in the contents of control soil in both seasons. Organic matter values were higher in wet season than in dry season, this may be attributed to increase in moisture content [22].

EC measures the electrical conductivities of the water-extracted from soils which is an indication of the relative water-soluble salt contents of the soil. It depends on the amount of dissolved minerals and gives the ability of a substance to conduct an electric current at a specific temperature, usually (25 °C) [23]. The range of EC values obtained in this study were lower than 108 to 201  $\mu\text{S}/\text{cm}$  values reported for soil samples around metal scrap dump in some parts of Delta State [24].

### 3.2. Heavy Metal Concentrations in Soils

Tables 2 and 3 show heavy metal concentrations in soil samples obtained from the five study areas for the dry and wet seasons respectively. The contents of Fe, Cu, Zn, Cd, Pb, and Cr varied from  $651.44 \pm 0.01$  to  $682.61 \pm 0.02$ ,  $0.76 \pm 0.00$  to  $2.96 \pm 0.00$ ,  $11.93 \pm 0.00$  to  $35.36 \pm 0.00$ ,  $0.29 \pm 0.00$  to  $0.58 \pm 0.00$ ,  $2.81 \pm 0.00$  to  $10.94 \pm 0.00$ , and  $1.45 \pm 0.00$  to  $4.81 \pm 0.02$  in dry season while the concentrations of Fe, Cu, Zn, Cd, Pb, and Cr ranged from  $534.41 \pm 0.00$  to  $549.28 \pm 0.01$ ,  $0.35 \pm 0.00$  to  $1.68 \pm 0.00$ ,  $6.19 \pm 0.01$  to  $32.06 \pm 0.00$ ,  $0.07 \pm 0.00$  to  $0.29 \pm 0.01$ ,  $2.34 \pm 0.00$  to  $5.00 \pm 0.00$  and  $1.06 \pm 0.00$  to  $1.45 \pm 0.00$  in wet season.

**Table 2:** Heavy Metal Concentrations in Soil Samples for the dry season (mg/kg)

Samplig sites	Fe	Cu	Zn	Cd	Pb	Cr
Karu	$682.61 \pm 0.02$	$1.55 \pm 0.00$	$17.35 \pm 0.00$	$0.29 \pm 0.00$	$8.82 \pm 0.00$	$1.45 \pm 0.00$
Kugbo	$651.43 \pm 0.01$	$2.96 \pm 0.00$	$23.12 \pm 0.01$	$0.40 \pm 0.00$	$10.69 \pm 0.00$	$3.61 \pm 0.00$
Nyanya	$681.68 \pm 0.01$	$0.76 \pm 0.00$	$11.93 \pm 0.00$	$0.43 \pm 0.00$	$10.94 \pm 0.00$	$2.79 \pm 0.00$
Apo	$675.12 \pm 0.02$	$0.90 \pm 0.00$	$35.36 \pm 0.00$	$0.58 \pm 0.00$	$4.00 \pm 0.00$	$4.81 \pm 0.02$
Lugbe	$678.30 \pm 0.01$	$1.72 \pm 0.00$	$13.09 \pm 0.02$	$0.34 \pm 0.00$	$2.81 \pm 0.00$	$4.11 \pm 0.00$
Control	$452.33 \pm 0.02$	$0.05 \pm 0.00$	$6.42 \pm 0.01$	$0.13 \pm 0.00$	$2.38 \pm 0.00$	$1.38 \pm 0.00$

**Table 3:** Heavy Metal Concentrations in Soil samples for wet Season (mg/kg)

Sampling sites	Fe	Cu	Zn	Cd	Pb	Cr
Karu	$546.28 \pm 0.01$	$0.65 \pm 0.00$	$12.65 \pm 0.00$	$0.16 \pm 0.00$	$4.69 \pm 0.02$	$1.29 \pm 0.00$
Kugbo	$534.41 \pm 0.01$	$1.68 \pm 0.00$	$15.76 \pm 0.01$	$0.10 \pm 0.00$	$5.00 \pm 0.00$	$1.14 \pm 0.00$
Nyanya	$543.47 \pm 0.01$	$0.35 \pm 0.00$	$6.19 \pm 0.01$	$0.13 \pm 0.00$	$3.53 \pm 0.00$	$1.06 \pm 0.00$
Apo	$534.41 \pm 0.00$	$0.54 \pm 0.00$	$32.06 \pm 0.00$	$0.29 \pm 0.00$	$3.07 \pm 0.00$	$1.45 \pm 0.00$
Lugbe	$549.28 \pm 0.01$	$0.76 \pm 0.00$	$7.2 \pm 0.00$	$0.07 \pm 0.00$	$2.34 \pm 0.00$	$1.06 \pm 0.00$
Control	$169.85 \pm 0.01$	$0.10 \pm 0.00$	$4.10 \pm 0.00$	$0.01 \pm 0.00$	$1.89 \pm 0.00$	$0.99 \pm 0.00$

Values of iron (Fe) obtained from the study areas were far lower than the values reported for Levels of Pb, Fe, Cd and Co in soils of automobile workshop in Osun State, Nigeria [18, 19, 21], but higher than the values reported for heavy metal concentrations in soils, plant leaves and crops grown around dump sites in Lafia Metropolis and the



Impact of Nigerian flood disaster on the soil quality of farmlands respectively [26, 21]. Iron had the highest concentrations in all the sites. This is because it has been reported that natural soils contain significant concentration of iron [21]. Other things that may contribute to the high concentrations include wastes generated in these study areas which includes solvent, hydraulic fluid, spent lubricants most of which are dumped directly into the soil for so many years.

Copper (Cu) values were higher than that of the control site. The concentrations obtained in this study were all below 36mg/kg WHO standard. The presence of copper in the soil of the study areas could be as a result of mechanic wastes containing electrical and electronic parts, such as copper wires, electrodes and copper pipes and alloys from corroding vehicle scraps which have been deposited on the soils for a long time.

Zinc (Zn) concentrations obtained from the soil samples were all below 50mg/kg standard. Similar levels have been reported for heavy metals concentration in soil and *Amaranthus retroflexus* grown on irrigated farmlands in the Makera Area, Kaduna [27]. Presence of zinc in the soil could be as a result of elements from the lubricating oils and metal scraps from vehicles.

Concentration of cadmium (Cd) obtained from these study areas were below WHO permissible limit of (0.8mg/kg). The presence of cadmium could be due to the dumping of Poly vinyl chloride (PVC) plastics, nickel-cadmium batteries, motor oil, vehicle wheel and disposal sludge in the auto-mechanic shops [28].

Lead (Pb) concentrations obtained were below 85mg/kg WHO standard. Lead concentration may have resulted from lead containing compounds being used in the automobile workshops.

Chromium (Cr) concentrations obtained from the soil samples were below 100 mg/kg. The major source of chromium is from chromium containing wastes, especially industrial effluents. Chromium is commonly found at contaminated sites in form of chromium (VI) and it is the dominant form of chromium in shallow aquifers where aerobic conditions exist [21].

### 3.3. Heavy Metal Concentrations in Vegetables

Tables 4 -7 show the heavy metal concentrations in the two vegetables *Corchorous olitorius* and *Amaranthus hybridus* in dry and wet seasons respectively.

**Table 4:** Levels of Heavy Metals in Vegetable Samples *Corchorous olitorius* for Dry Season (mg/kg)

Sampling sites	Fe	Cu	Zn	Cd	Pb	Cr
Karu	82.43±0.01	0.06±0.00	2.50±0.01	0.18±0.00	1.25±0.00	0.91±0.00
Kugbo	201.56±0.01	0.58±0.00	4.67±0.00	0.11±0.00	2.30±0.00	1.06±0.00
Nyanya	197.77±0.01	0.04±0.00	5.77±0.00	0.07±0.00	8.44±0.00	0.90±0.00
Apo	105.29±0.01	0.04±0.00	0.23±0.00	0.05±0.00	3.75±0.00	1.14±0.00
Lugbe	119.24±0.00	0.41±0.00	1.42±0.00	0.07±0.00	0.56±0.00	1.06±0.00
Control	113.29±0.01	0.03±0.00	0.12±0.01	BDL	0.13±0.00	0.07±0.00

BDL = Below detection limit

**Table 5:** Levels of Heavy Metals in Vegetable Samples *Amaranthus hybridus* for Dry Season (mg/kg)

Sampling sites	Fe	Cu	Zn	Cd	Pb	Cr
Karu	87.85±0.01	0.09±0.00	2.67±0.00	BDL	1.32±0.00	0.63±0.00
Kugbo	210.57±0.00	0.61±0.00	4.00±0.00	BDL	2.11±0.00	0.96±0.00
Nyanya	178.90±0.01	6.24±0.00	5.12±0.00	BDL	7.76±0.00	0.78±0.00
Apo	107.10±0.00	0.09±0.00	2.00±0.01	0.03±0.00	3.12±0.00	1.18±0.00
Lugbe	121.08±0.01	0.50±0.00	1.12±0.00	0.04±0.01	0.43±0.01	0.87±0.00
Control	97.01±0.01	0.02±0.00	0.11±0.00	BDL	0.10±0.00	0.05±0.00

BDL = Below detection limit

**Table 6:** Levels of Heavy Metals in Vegetable Sample *Corchorous olitorius* for Wet Season (mg/kg)



Sampling sites	Fe	Cu	Zn	Cd	Pb	Cr
Karu	42.75±0.00	0.08±0.00	0.58±0.00	0.10±0.00	1.89±0.00	0.49±0.00
Kugbo	99.00±0.01	0.10±0.00	0.61±0.00	0.05±0.00	2.44±0.00	0.43±0.00
Nyanya	91.33±0.01	0.03±0.00	0.70±0.01	0.02±0.00	1.81±0.00	0.31±0.00
Apo	73.98±0.00	0.10±0.00	0.11±0.00	0.01±0.00	1.63±0.00	0.77±0.00
Lugbe	79.10±0.01	0.14±0.00	0.43±0.00	0.01±0.00	0.44±0.00	0.87±0.00
Control	26±0.01	0.06±0.00	0.01±0.00	BDL	0.25±0.00	0.03±0.00

BDL = Below detection limit

**Table 7:** Levels of Heavy Metals in Vegetable Sample *Amaranthus hybridus* for Wet Season (mg/kg)

Sampling sites	Fe	Cu	Zn	Cd	Pb	Cr
Karu	44.15±0.01	0.10±0.00	0.53±0.00	0.05±0.00	1.83±0.00	0.50±0.01
Kugbo	87.12±0.00	0.16±0.00	0.59±0.00	0.09±0.00	1.99±0.00	0.51±0.00
Nyanya	57.45±0.00	0.05±0.00	0.67±0.00	0.02±0.00	1.82±0.00	0.31±0.00
Apo	75.71±0.01	0.16±0.00	0.14±0.00	0.01±0.00	0.97±0.00	0.69±0.00
Lugbe	79.62±0.00	0.17±0.00	0.50±0.00	0.03±0.00	0.52±0.00	0.83±0.00
Control	28.97±0.01	0.04±0.00	0.01±0.00	BDL	0.27±0.00	0.04±0.00

BDL = Below detection limit

Concentration of iron in *Corchorous olitorius* in wet (Table 6) and dry (Table 4) seasons differed from 42.75±0.00 to 99.00±0.01 mg/kg and 82.43±0.01 to 201.56±0.01 mg/kg respectively, while the concentration in *Amaranthus hybridus* in wet (Table 7) and dry (Table 5) seasons ranged from 44.15±0.01 to 87.12±0.00 mg/kg and 87.85±0.01 to 210.57±0.00 mg/kg respectively. Concentrations of iron in the two vegetables were all below (425mg/kg) WHO/FAO standard.

Copper contents in *Corchorous olitorius* in wet and dry seasons ranged from 0.03±0.00 to 0.14±0.00 mg/kg and 0.04±0.00 to 0.58±0.00 mg/kg respectively, while it varied from 0.05±0.00 to 0.17±0.00 mg/kg and 0.09±0.00 to 6.24±0.00 mg/kg in wet and dry seasons respectively for *Amaranthus hybridus*. Concentrations of copper in the two vegetables were all below WHO/FAO standard (10 mg/kg). The values obtained were in agreement with that reported by [27] and lower than that reported by [18].

Zinc concentrations in *Corchorous olitorius* in wet and dry seasons varied from 0.11±0.00 to 0.70±0.01 mg/kg and 0.23±0.00 to 5.77±0.00 mg/kg respectively while the concentrations in *Amaranthus hybridus* in wet and dry seasons ranged from 0.14±0.00 to 0.67±0.00 mg/kg and 1.12±0.00 to 5.12±0.00 mg/kg respectively. Zinc concentrations were above WHO/FAO standard (0.6mg/kg) in *Corchorous olitorius* except that obtained from Apo site in the two seasons. Also, the heavy metal concentrations in *Amaranthus hybridus* were above standard except that obtained from Karu, Apo and Lugbe sites in the wet season. The values obtained were in the range reported for heavy metals accumulation in cabbage, lettuce and carrot irrigated with wastewater from Nagodi mining site in Ghana [29]. The values were lower than the levels reported for [27], but higher than that reported for [26].

Cadmium levels in *Corchorous olitorius* varied from 0.01±0.00 to 0.10±0.00 mg/kg and 0.05±0.00 to 0.18±0.00 mg/kg in wet and dry seasons respectively, while it ranged from 0.01±0.00 to 0.09±0.00 mg/kg and 0.03±0.00 to 0.04±0.00 mg/kg in *Amaranthus hybridus* in wet and dry seasons respectively. Cadmium concentrations in the two vegetables were above the standard (0.02mg/kg) in Karu, Kugbo and Lugbe sites in wet season. However, in dry season, it was above the standard in *Corchorous olitorius* from the five study areas.

Concentrations of lead in *Corchorous olitorius* in wet and dry seasons varied from 0.44±0.00 to 2.44±0.00 mg/kg and 0.56±0.00 to 8.44±0.00 mg/kg respectively, while *Amaranthus hybridus* values ranged from 0.52±0.00 to 1.99±0.00 mg/kg and 0.43±0.00 to 7.76±0.00 mg/kg in wet and dry seasons respectively. Lead concentrations in *Amaranthus hybridus* in wet season were below standard (2.00mg/kg), similar trend was observed in *Corchorous olitorius*, except for the level obtained at Kugbo site. In dry season, the concentrations in the two vegetables were above standard except concentrations obtained from Karu and Lugbe sites.



Chromium concentrations in *Corchorous olitorius* in wet and dry seasons ranged from  $0.31\pm 0.00$  to  $0.87\pm 0.00$  mg/kg and  $0.90\pm 0.00$  to  $1.16\pm 0.00$  mg/kg respectively while the level in *Amaranthus hybridus* ranged from  $0.31\pm 0.00$  to  $0.83\pm 0.00$  mg/kg and  $0.63\pm 0.00$  to  $1.18\pm 0.00$  mg/kg in wet and dry seasons respectively. The concentrations were slightly below WHO/FAO standard (1.30mg/kg) in the two vegetables.

The results revealed that in the vegetables, concentrations of heavy metals in dry season were higher than that in wet season. The concentrations of these metals in the vegetables were all above those obtained from the control site except iron from control site which is higher than that from Karu site. The results also showed that iron has the highest concentration in the vegetables.

### 3.4. Heavy Metal Transfer Factors (TF)

Figures 2-5 show heavy metal transfer factors from soil to the two vegetables in dry and wet seasons respectively

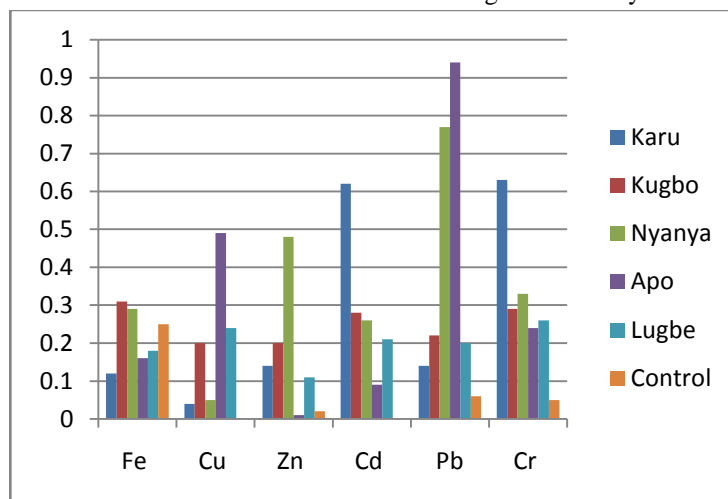


Figure 2: Heavy Metal Transfer Factors (TF) from Soil to Vegetable *Corchorous Olitorius* in Dry Season

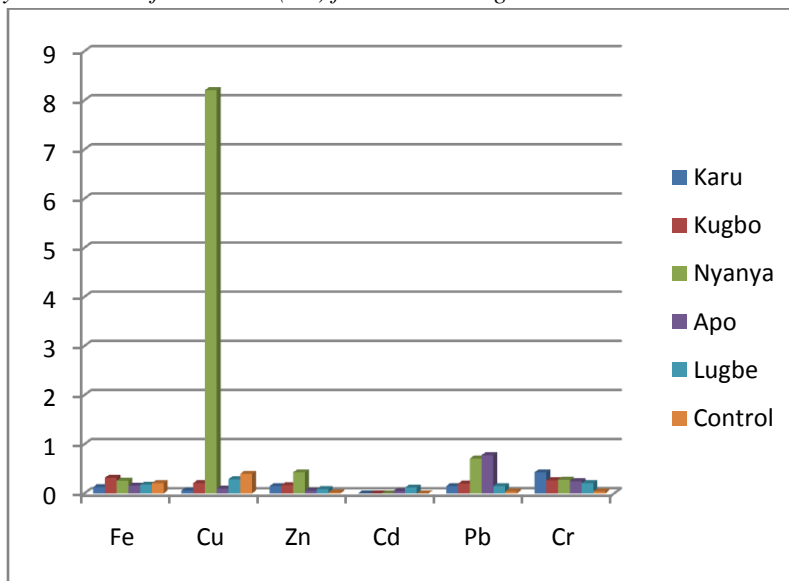


Figure 3: Heavy Metal Transfer Factors (TF) from Soil to Vegetable *Amaranthus hybridus* in Dry Season



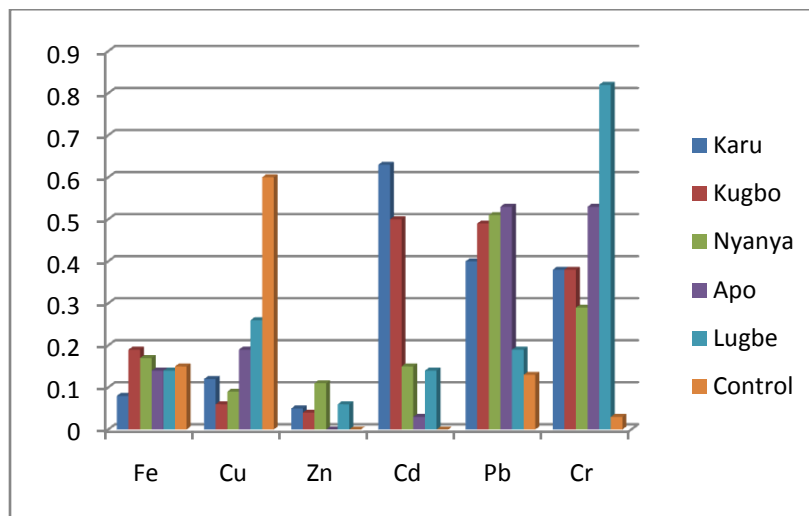


Figure 4: Heavy Metal Transfer Factors (TF) from Soil to Vegetable *Corchorous Olitorius* in Wet Season

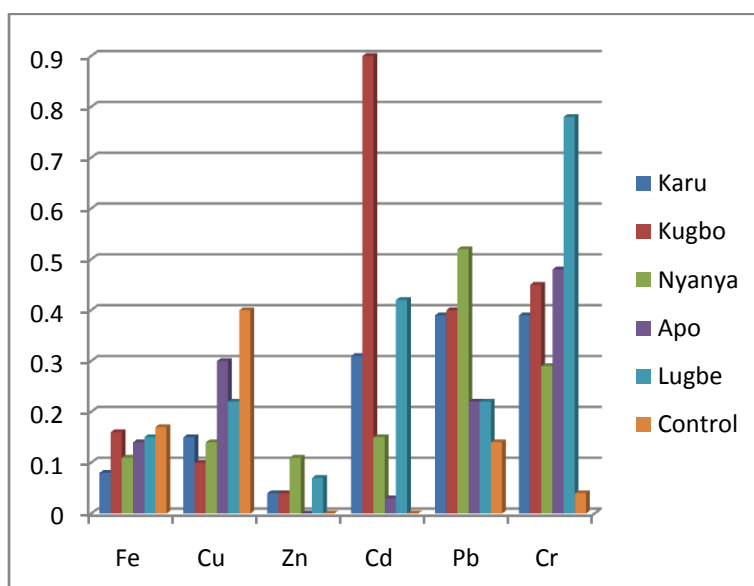


Figure 5: Heavy Metal Transfer Factors (TF) from soil to vegetable *Amaranthus hybridus* in wet Season

Heavy Metal (TF) indicates that in *Corchorous olitorius* TFs were between 0.01 - 0.94 in dry season (Figure 2) and 0.00 – 0.82 in wet season (Figure 4). In dry season, lead accumulated the most in the vegetables at Apo with TF of 0.94. In wet season, chromium had the highest TF of 0.82 at Lugbe, followed by cadmium with TF of 0.63 at Karu site. This might be due to higher mobility of cadmium in soil and low retention than other toxic cations [30].

Figure 3 shows that in *Amaranthus hybridus*, copper had TF of 8.21 in Nyanya during the dry season, while cadmium (Figure 5) had the highest TF of 0.90 at Kugbo during the wet season. TF values of the heavy metals for the two vegetables varied between the species and sites. Higher value of TF suggests poor retention of metals in soil and or more translocation in vegetables, because metals with high TF are easily transferred to the edible parts of vegetables than the ones with low TF [31]. The higher uptake of heavy metals in vegetables may be due to higher transpiration rate to maintain the growth and moisture content of the vegetables [32]. TF < 1 indicates low accumulation characteristics of metals in the vegetable species [33].



**Table 8:** Heavy Metals Standard Permissible Limit for Soils and Vegetables [34]

Metals	WHO/FAO(vegetables)	Dutch/WHO (soil)
Fe	425.00	-
Cu	10.00	36.00
Zn	0.60	50.00
Cd	0.02	0.80
Pb	2.00	85.00
Cr	1.30	100.00

#### 4. Conclusion

The soil samples collected from the automobile workshops in rainy and dry seasons showed that the heavy metals analyzed were present in considerable amounts when compared with their corresponding control samples and this suggests soil contamination. There was an indication that zinc, cadmium and lead levels in vegetables analyzed were above WHO standard. Generally higher heavy metal concentrations were recorded in soils and vegetables during the dry season than in the wet season, and in these seasons, the soils were polluted mainly with iron, zinc and lead. Fe had the highest values in dry and wet seasons, while cadmium had the lowest values in both seasons.

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