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## Physicochemical Characteristics of Soil and Health Risk Assessment of Potentially Toxic Metals in Soil and Vegetables from Roadside Farmlands in Iwo, Southwestern Nigeria

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## ABSTRACT

This study assessed the levels of potentially toxic metals in soil and vegetables from farmlands along major roads in Iwo, Southwestern Nigeria. Health risk assessments were performed by assessing chronic daily intake (CDI) for soil and target hazard quotient (THQ) for vegetables. The results showed that concentrations of potentially toxic metals in vegetables assessed were significantly higher at farmland sites along the major roads compared to that of the control site. The calculated CDI for carcinogenic risks were below the minimal risk level while the non-carcinogenic risks for adults were higher than those of the children. The THQ for both children and adults were above the 1.0 value stipulated by USEPA as safety limit indicating that regular consumption of these vegetables over a prolonged period of time could expose the consumers to significant health risks.

### 1. Introduction

Agricultural practice is the mainstay of several communities in Nigeria engaging about 75% of the total labour force of especially low income earners available within the country [1, 2]. Very often, for reasons of proximity and accessibility, land spaces within the vicinity of roads are usually converted to arable lands where food crops including vegetables are planted. However, the environmental concern of such practice includes physical disturbance of the surrounding landscape, traffic emission, settling of contaminant-bearing emitted dust on food crops and incursion of highway runoff on the nearby farmlands.

One of the most direct and regular repercussions of such practice is the introduction of elevated levels of potentially toxic metals into the soil of such roadside farmlands [3, 4]. Elevated levels of potentially toxic metals in vegetables may also be due to long term uses of treated and untreated waste water [5-8], addition of manures, sewage sludge, fertilizers and pesticides [9], which may affect the uptake of heavy metals by modifying the physico-chemical properties of the soil such as pH, organic matter, and bioavailability of potentially toxic metals in the soil. Rapid and unorganized industrialization and urbanization have contributed to the elevated levels of heavy metals in the urban environment of the developing countries such as Nigeria [4] and South Africa [3].

Excessive accumulation of heavy metals in agricultural soils around roadside areas results in elevated heavy metal uptake by food crops via plant roots as well as direct deposition of contaminants from the atmosphere onto plant surfaces [10]. This is of great concern because of the associated health risks to the local inhabitants and consumers of such food crops [11-13]. Potentially toxic metal contamination of food items is one of the most important aspects of food quality assurance [14-17]. International and national regulations on food quality have lowered the maximum permissible levels of toxic metals in food items due to an increased awareness of the risk these metals pose to food chain contamination [16].

Green leafy vegetables are important part of diets generally in Nigeria, and especially among the people of Southwestern part of Nigeria. Vegetables constitute an important part of human diet because of their high nutritional contents including carbohydrates, proteins, vitamins, minerals and fibers required for human health. They also act as

neutralizing agents for acidic substances formed during digestion [18]. The uptake and bioaccumulation of heavy metals in vegetables are influenced by many factors, such as climate, atmospheric depositions, the concentrations of heavy metals in soils, the nature of soil and the degree of maturity of the plants at the time of the harvest [19, 20].

Studies on soil and vegetation of heavy metal-contaminated sites as a result of pollution due to traffic emission, emitted dust and highway runoff are essential for an insightful assessment of metal toxicity of soils and aerial plants of such sites. Apart from using the information obtained to evaluate the possible toxic impacts on animals and human health, valuable information for phytoremediation of metalliferous sites are also provided [21].

The aim of the present study was to assess the levels of some potentially toxic metals in three Nigerian vegetables (*Amaranthus viridis*, *Celosia argentea* and *Corchorus olitorus*) obtained from farmlands along major roads in Iwo and to determine the physico-chemical properties of the soil.

### 2. Experimental Methods

#### 2.1 Description of Study Area

The study was carried out in Iwo, one of the major towns in Osun State, Southwestern Nigeria. Iwo is located 35 km away from Osogbo (the state capital) on latitude 07° 38'N and longitude 004° 11'E. Two out of the three sampling points (Ori-Eeru and Feesu) were located along the Osogbo-Ibadan express road, a road associated with daily heavy traffic density, with filling stations, market areas, road junctions, shopping malls, automobile workshops and metal works (iron benders and welders) randomly sited along the streets and highways [22]. The third location was the Agricultural Research Farm of Bowen University, Iwo. This location was far away from high traffic density and serves as the control site. The GPS of these locations are given in the Table 1.

**Table 1** Sampling site locations obtained by GPS

Location	N- Coordinate	E – Coordinate
Ori-Eeru	07° 39.300'	004° 12.305'
Feesu	07° 39.412'	004° 10.997'
Bowen	07° 37.400'	004° 11.636'

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## 2.2 Collection and Treatment of Samples

Soil and vegetable samples were collected in May, 2015. Freshly harvested leafy vegetables, namely: Amaranthus (Yoruba: Tete) (*Amaranthus viridis*), Celosia (Yoruba: Soko) (*Celosia argentea*) and Corchorus (Yoruba: Eweddu) (*Corchorus olitorus*) and soil samples from the marked locations were collected into different properly labelled zip-block polyethylene bags and transported to the laboratory for immediate analysis. The plant samples were washed with doubly distilled water and spread on clean plastic trays to allow water to drain off. The plant samples were later separated into different plant parts and dried at a temperature of 105 °C in an oven to a constant weight. The dried plant samples were ground using an agate mortar and pestle and stored in labelled clean plastic bottles. The soil samples were air-dried at ambient temperature on an inert surface in a ventilated cupboard to prevent or minimize cross contamination of samples with the atmospheric particulates. Unwanted particles such as humus and pebbles were handpicked from the air-dried soil samples. The samples were thereafter ground using an agate mortar and pestle. The powdered soil samples were sieved using a 150 µm pore size sieve.

## 2.3 Determination of Some Soil Physicochemical Parameters

The pH, conductivity and temperature of the soil samples were determined using hand-held pH meter, conductivity meter, and thermometer, respectively. Total organic carbon and total organic matter were determined using the chromic acid oxidation method [23]. Sulphate, phosphate, chloride, and nitrate levels were determined using turbidimetric, colorimetric, argentometric titration and brucine colourimetric methods, respectively [24].

## 2.4 Digestion of Plant and Soil Samples

Accurately weighed 1.0 g of each of dried vegetable samples was digested with a mixture of 5 ml of (1:2) perchloric: nitric acid in a Teflon beaker placed on a thermostated hot plate for 1 h at 120 °C in a fume cupboard. Replenishing with the acid mixture was done as necessary to prevent total dryness. The hot beaker with its content was brought down and allowed to simmer for about 10 minutes. Thereafter, about 2 mL of the acid mixture was added and further digestion was carried out at a temperature of 150 °C for 30 min by which time a clear solution was obtained. Similarly, accurately weighed 0.3 g each of soil the samples was digested with 5 mL of a 3:2 mixture of HNO<sub>3</sub>:HClO<sub>4</sub> for 1 h 30 min. With occasional replenishment at a temperature of 150 °C. Later, 2 mL of HF was added and digestion at 180 °C was done for a further time of 30 min. Appropriate blanks were prepared to check for background contaminants by the reagent used. The digested samples were quantitatively transferred to a 25 mL volumetric flask and made to the mark with distilled water. The digested samples were analyzed for their potentially toxic metal content using PG990 Atomic Absorption Spectrophotometer available at the Central Science Laboratory, Bowen University, Iwo, Nigeria. Actual values of metal concentration, [M]<sub>a</sub>, in a sample is calculated from the relationship:

$$[M]_a = [M]_i \times \text{d.f.}$$

where [M]<sub>i</sub> is the instrumental metal concentration; and d.f. is the dilution factor.

**Table 2** Physicochemical parameters\*and total metal levels of the soil samples

Site	Temp. (°C)	pH	NO <sub>3</sub> <sup>-</sup> (ppm)	PO <sub>4</sub> <sup>3-</sup> (ppm)	Cl <sup>-</sup> (ppm)	SO <sub>4</sub> <sup>2-</sup> (ppm)	%TOC	%TOM	EC (µS/cm)	ORP (mV)	Total metal levels in the farmland soils (mg/kg)		
											Pb	Cu	Zn
Ori-Eeru	27.10	5.60	3.69	137.81	267.42	2.92	1.77	2.62	261.90	347	28.2±0.5	20.5±1.7	64.2±7.0
Feesu	28.50	7.50	2.96	137.93	212.70	0.08	1.52	3.05	255.50	348	23.9±1.0	12.5±0.6	93.1±0.9
Bowen	27.90	5.50	2.89	130.52	226.88	0.03	0.63	1.09	884.60	349	7.00±9.9	5.16±0.2	47.4±0.5
Mean	27.83	6.20	3.18	135.42	235.67	1.01	1.31	2.25	467.33	348	19.7±11.2	12.7±7.7	68.2±23.1
±S.D.	±0.57	±0.19	±0.14	±3.47	±10.18	±0.06	±0.11	±0.12	±20.06	±1			
CV	2.05	3.06	4.40	2.56	4.32	5.94	8.40	5.33	4.29	0.29	56.9	60.6	33.9
WHO, 2006	<32	6.5-8.5	10.00	130.00	250.00	-	-	-	1000	-	-	-	-

\*Values are in mg/kg except where otherwise indicated

## 3. Results and Discussion

### 3.1 Physicochemical Parameters of Soil Samples

The physicochemical parameters and total metal levels of the farmland soils are listed in Table 2.

#### 3.1.1 Soil Temperature

The soil temperatures ranged from 27.10 °C at Ori-Eeru to 28.50 °C at Feesu. The optimum temperature for plant growth ranges from 15 °C to 40 °C [27]. All the soil temperature values fell within this range which was an

### 2.5 Health Risk Assessment of Metals in Farmland Soils

The potential health risk assessment of farmland soil was assessed using the relationship described elsewhere [25]:

$$\text{Carcinogenic index (mg/kg/day)} = \text{Cs} \times \text{IF} \times \text{EF} / \text{AT}$$

where IF = IR adult × ED adult / BW adult + IR child × ED child / BW child

$$\text{Non-carcinogenic index (mg/kg/day)} = \text{Cs} \times \text{IN} \times \text{EF} \times \text{ED} / \text{BW} \times \text{AT}$$

### 2.6 Health Risk Assessment of Metals in Vegetables

Potential health risks of trace metals exposure to residents of Iwo as a result of consumption of these three vegetables were assessed using target hazard quotient (THQ) which is defined as the ratio of the body intake dose of a pollutant to the reference dose. Target hazard quotient (THQ) was first proposed by USEPA for assessing the potential health risks of pollutant exposure to human health [26] in which case THQ > 1 implies that a potential risk is associated with the pollutant under consideration, and THQ < 1 implies that there is no obvious potential risk associated with the pollutant. The equations used to calculate the THQ for single pollutant, THQ<sub>single</sub>, and THQ for total pollutant, THQ<sub>total</sub>, are respectively given as:

$$\text{THQ}_{\text{single}} = [\text{Cs} \times \text{IR} \times \text{veg} \times \text{EF} \times \text{ED} / \text{BW} \times \text{AT} \times \text{RfD}] \times 10^{-3};$$

$$\text{and } \text{THQ}_{\text{total}} = \sum \text{THQ}_{\text{(single pollutant)}}$$

where Cs is the concentration of the metal in soil, IF is the intake factor, EF is the exposure frequency, AT is the averaging time for non-carcinogenic, IR is the ingestion rate, IN is the inhalation rate, ED is the exposure duration and BW is the body weight, and RfD is the reference dose.

### 2.7 Quality Control Measures Adopted

Appropriate quality assurance procedures and precautions were carried out to ensure reliability of the results for the different environmental media under investigation. Doubly distilled water was used throughout the study. Glassware was properly cleaned, and all the reagents used were of analytical grade. Reagent blank determinations were used to correct the reagent and apparatus additions to the amount of analytes of interest. For validation of analytical procedures, a recovery study was carried out by spiking and homogenizing several already analyzed samples with varying amounts of standard solutions of the metals. Blank and drift standards were run after every sample determination to maintain instrumental calibration. The coefficient of variation of replicate analyses was determined for the measurements to evaluate analytical precision.

### 2.8 Statistical Analysis of Data

Apart from analysis of variance that was performed on each measured variable, means and standard errors (SE) were also calculated. The least significant difference (p<0.05) was used for multiple comparison among treated mean using the SPSS software package.

indication that, temperature wise, the farmlands were suitable for vegetable growth.

#### 3.1.2 Soil pH Values

To a large extent, soil pH affects a substantial portion of soil chemistry including the mobility of heavy metals in soil. It has been found that soil pH is correlated with the availability of nutrients to the plant [27, 28]. Consequently, lower pH would favour availability, mobility and redistribution of metals in the various fractions of soil because as pH decreases, the solubility of metallic elements in the soil increases and they

become more readily available to plants [29-31]. However, at pH values lower than 5.5, phosphate ions can react with soluble iron, manganese and aluminium ions to form insoluble phosphates [27]. In the present study, soil pH ranged from 5.5 at Bowen farmland to 7.5 at Feesu farmland indicating a moderate acidic to a neutral soil pH condition. Moderately acidic soil favours increased nutrient solubility and availability [32], thus soils from the Bowen University Agricultural Farm site may tend to have an increased micronutrient solubility and mobility as well as increased potentially toxic metal solubilization in the soil.

### 3.1.3 Soil Nitrate Levels

The maximum level of  $\text{NO}_3^-$  was found at Ori-Eeru which was 3.69 ppm while the lowest levels were found at Bowen Agricultural farm which was 2.89 ppm. These results are in agreement with the results reported in a similar study [33] indicating that the  $\text{NO}_3^-$  level in top soil layer was low. The reason for the low levels of  $\text{NO}_3^-$  in top soil layers could be because of percolation and leaching of  $\text{NO}_3^-$  through the agent of soil erosion due to high solubility of  $\text{NO}_3^-$  generally.

### 3.1.4 Organic Carbon and Soil Organic Matter

Total organic carbon (TOC) is the carbon (C) stored in soil organic matter (SOM) [34]. Organic carbon (OC) enters the soil through the decomposition of plant and animal residues, root exudates, living and dead microorganisms, and soil biota. Soil organic matter is the organic fraction of soil exclusive of non-decomposed plant and animal residues. Organic acids, such as oxalic acid, commonly released from decomposing organic residues and manures, prevents phosphorus fixation by clay minerals and improve its plant availability, especially in subtropical and tropical soils. An increase in SOM, and therefore total C, leads to greater biological diversity in the soil, thus increasing biological control of plant diseases and pests. Also, the presence of organic carbon increases the cation exchange capacity of the soil and retains nutrients to be assimilated by plants. Soil organic matter (SOM) enhances the usefulness of soils for agricultural purposes as it supplies essential nutrients and has unexcelled capacity to hold water and absorb cations. It also functions as a source of food for soil microbes and thereby helps enhance and control their activities [35].

Total organic carbon in the soils under investigation ranged from  $0.63 \pm 0.02$  to  $1.77 \pm 0.04\%$  as indicated in Table 1. The moderately high amount of organic carbon of the farmland soils is suggestive of degradation or presence of degradable and compostable wastes [36]. The organic matter in the soil samples varied from  $1.09 \pm 0.06$  to  $3.05 \pm 0.08\%$ . The Feesu soils contained high amount of organic matter, about  $3.05 \pm 0.08\%$  which may be responsible for increase in the soil pH as compared to that of the Bowen soil. This observation was supported by an earlier report [37] that farmland sites had significantly higher pH regime and soil organic matter as compared to the control soil. It was also demonstrated that high OM ( $>2.0\%$ ) in soils is conducive for the formation of heavy metal chelation [38].

### 3.1.5 Soil Electrical Conductivity

The variation of electrical conductivity (EC) within the sampling stations is given in (Table 1). The EC of the farmland soils ranged from  $255.50 \mu\text{S}/\text{cm}$  to  $884.60 \mu\text{S}/\text{cm}$ . All the EC values were below the recommended maximum limit of  $1000 \mu\text{S}/\text{cm}$  for soil [39]. Hence, the agricultural soils, from the point of view of their EC values, would support smooth plant growth; plant wilting resulting from stronger soil electrolytes with respect to the cellular content of plants would be avoided.

### 3.1.6 Chloride Level in the Soil Samples

Chlorine occurs in form of chloride ion in soil and is considered a micronutrient that helps to regulate the osmotic absorption of other nutrients that plants require. It often accumulates in foliar tissues at levels of 2 – 20 mg/kg of dry matter, although plants require 10 to 100 times less to grow properly [27]. Chloride ion in the soil samples ranged between  $212.70 \text{ mg}/\text{kg}$  at Feesu and  $267.42 \text{ mg}/\text{kg}$  at Ori-Eeru. Although the chloride levels in the soils of the study area were either slightly lower or comparable to the  $250 \text{ mg}/\text{kg}$  value set for agricultural soils [39], a level of  $180 \text{ mg}/\text{kg}$  in lighter type soils is considered the upper range for some crops production; higher levels could reduce soil microbe populations and slow down nitrogen conversion rates [27]. The relatively elevated levels of chloride ion detected in the soils of the study area might be a reflection of significant presence of anthropogenic addition of chloride rich chemicals associated with the municipal solid waste, poultry feed formulations, supplements, fertilizers and sewage all of which are regularly available and used in one way or the other by people of the study area.

### 3.1.7 Soil Phosphate Level

Phosphate in soil can be of natural or anthropogenic origin. It occurs naturally in rocks and other mineral deposits as orthophosphate anions, metaphosphate (or polyphosphate) and in weathered soils as soluble phosphates or organically bound phosphate. Phosphorus is the second most critical element influencing plant growth and production throughout the world [27]. Anthropogenic sources of phosphate in soil could be from municipal sewage, industrial effluent, detergents and phosphate related fertilizers used on agricultural soils. Depending on the soil pH, phosphorus in soil is taken up by plants as orthophosphate anions ( $\text{H}_2\text{PO}_4^-$ ,  $\text{HPO}_4^{2-}$ ). Table 2 shows the result of total  $\text{PO}_4^{3-}$  concentrations in samples at three sites. The maximum amount of soil P required for agricultural crops (Agronomic Critical Level) is 30-40 ( $69.00-92.00 \text{ ppm}$  as  $\text{PO}_4^{3-}$ ) [40]. The levels of  $\text{PO}_4^{3-}$  in the soil samples were greater than the amount of soil  $\text{PO}_4^{3-}$  required for agricultural crop i.e. higher than the permissive levels since the recommended environmental levels of P soil content (Environmental Critical Level) in most countries is 60 ( $137 \text{ ppm}$  as  $\text{PO}_4^{3-}$ ) [40]. High levels of total  $\text{PO}_4^{3-}$  in soil samples are due to several reasons. First, there is already  $\text{PO}_4^{3-}$  in soil, the bulk of the soil P is either in the soil organic matter or in the soil minerals [27]. Second, it is clear that there is excessive usage of  $\text{PO}_4^{3-}$  fertilizers whether industrial or natural from manure at two locations in the catchment. From Table 1, the highest level of  $\text{PO}_4^{3-}$  was found at Ori-Eeru which is  $137.93 \text{ ppm}$ . Similar studies reported that top soil of farmland along roadsides has higher levels of total phosphorus [41, 42].

### 3.1.8 Oxidation-Reduction Potential (ORP or $E_h$ ) Values in Soil

The  $E_h$  values of soils reflect the extent of aeration of the soil because, at any point in time, the chemical elements in the soil are in a certain oxidation and reduction state, depending on the level of soil aeration. For example, in well aerated soils, iron exists as  $\text{Fe}^{3+}$ , soil nitrogen exists as  $\text{NO}_3^-$ , while sulphur exists as  $\text{SO}_4^{2-}$  [27]. Positive and high  $E_h$  values indicate strong oxidizing or oxic conditions while low and negative values indicate anoxic conditions under which elements would exist in reduced forms. The  $E_h$  values of soils in the present study ranged from 347 – 349 mV. Thus, the soils could be classified as moderately well-oxidized soils whose  $E_h$  values are stated as approximately 300 mV [27]. Most of the  $\text{PO}_4^{3-}$  and  $\text{NO}_3^-$  ions are also moderately available at these  $E_h$  values.

### 3.1.9 Levels of Potentially Toxic Metals in Soil

The concentrations of potentially toxic metals (Cu, Pb and Zn) in the soils of the farmlands studied are presented in Table 2. Generally, potentially toxic metal concentrations in the farmland soils of Feesu and Ori-Eeru were significantly higher (at  $P \leq 0.05$ ) than the values obtained from the farmland soils of the control site (Bowen Farmland). This was an indication of greater metal enrichment of those sites probably as a result of more exposure to anthropogenic activities such as vehicular emissions and uncontrolled dumping of metal-containing scraps and used items around the vicinity of the farmlands.

Copper levels ( $\text{mg}/\text{kg}$ ) in the soils ranged from  $5.2 \pm 0.2$  at the control site to  $20.5 \pm 1.7 \mu\text{g}/\text{g}$  at Ori-Eeru were lower than the range  $58.30$  to  $207.50 \text{ mg}/\text{kg}$  in Fadama soils along the bank of River Challawa, Nigeria [43], or the values  $19.8$  and  $39.0 \text{ mg}/\text{kg}$  in vegetable and orchard soils of Hong Kong, respectively [44], or the range  $1.61-3.92 \text{ mg}/\text{kg}$  in vegetable garden of Dar es Salam, Tanzania [45].

Lead in the soil samples ranged from  $7.00 \pm 9.9 \mu\text{g}/\text{g}$  at the control site to  $28.2 \pm 0.5 \mu\text{g}/\text{g}$  at Ori-Eeru. Again, these values were lower than the  $60$  to  $143.30 \text{ mg}/\text{kg}$  in Fadama soils along the bank of River Challawa, Nigeria [43], or  $38.2$  and  $120 \text{ mg}/\text{kg}$  in vegetable and orchard soils in Hong Kong, respectively [44], but significantly higher (at  $P \leq 0.05$ ) than the values  $1.18-8.23 \text{ mg}/\text{kg}$  in vegetable garden of Dar es Salam, Tanzania [45]. For Zn, the range in the soil samples ranged between  $47.4 \pm 0.5$  at the control site and  $93.1 \pm 0.9 \text{ mg}/\text{kg}$  at Feesu. These values fell within the range  $0.33$  to  $106.00 \text{ mg}/\text{kg}$  of Zn levels obtained in the orchard field soils in Korea [46], and comparable to the range of  $60.0$  to  $149 \text{ mg}/\text{kg}$  Zn in agricultural soils of Spanish agrarian basin [47] or the  $62.4$  and  $68.9 \text{ mg}/\text{kg}$  in vegetable and orchard soils of Hong Kong, respectively [44], but generally lower than the range  $52.2$  to  $227 \text{ mg}/\text{kg}$  Zn [48] in agricultural soils of Hainan and Chengdu province in China; and generally higher than the ranges  $10.1$  to  $32.6 \text{ mg}/\text{kg}$  Zn in garden soils of Bangalore urban district, India [49], and  $6.01$  to  $34.4 \text{ mg}/\text{kg}$  Zn in vegetable garden of Dar es Salam, Tanzania [45].

The results showed that Feesu soil sample had the highest metal exposure implying that this soil probably had greatest anthropogenic metal input. Copper levels were the lowest in all the soil samples; the maximum concentration of Cu ( $20.5 \mu\text{g}/\text{g}$ ) was obtained at Ori-Eeru, while the results remarkably demonstrated that Bowen Agricultural Farm soils had less anthropogenic heavy impacts than the other sites located by the

roadsides. The order of the concentration of metals was Zn > Pb > Cu. These results are in agreement with those reported in an earlier study [50] in which Cu concentration was the lowest in the soil samples of his study. The results showed that the accumulated concentration of heavy metals was lower than the maximum allowable level (Table 3).

**Table 3** Metal mean levels ( $\mu\text{g/g}$ ) in different vegetable parts from the various farm locations in Iwo

Site	Vegetable	Plant Part	Pb	Cu	Zn	Total metal/part
Ori-Eeru	<i>Corchorus olitorus</i>	Leaf	31.3	15.6	79.0	125.9
		Stem	41.2	16.5	119.1	176.8
		Root	28.7	20.1	161.3	210.1
		Total	101.2	52.2	359.4	512.8
	<i>Amaranthus viridis</i>	Leaf	47.9	15.6	129.3	192.8
		Stem	22.9	12.0	107.1	142.0
		Root	6.6	7.3	82.3	96.2
		Total	77.4	34.9	318.7	431.0
	<i>Celosia argentea</i>	Leaf	16.5	13.8	105.2	135.5
		Stem	31.4	26.5	133.0	190.9
		Root	32.8	16.5	108.2	157.5
		Total	80.7	56.8	346.4	483.9
Feesu	<i>Corchorus olitorus</i>	Leaf	4.6	21.7	234.2	260.5
		Stem	26.5	20.0	335.4	381.9
		Root	48.9	32.5	366.4	447.8
		Total	80.1	74.2	936.0	1090.2
	<i>Amaranthus viridis</i>	Leaf	29.4	20.9	378.1	428.4
		Stem	25.8	11.9	349.1	386.8
		Root	54.6	17.9	323.0	395.5
		Total	109.8	50.7	1050.2	1210.7
	<i>Celosia argentea</i>	Leaf	36.0	21.5	313.6	371.1
		Stem	12.7	8.0	246.4	267.1
		Root	5.7	8.0	199.5	213.2
		Total	54.4	37.5	759.5	851.4
Bowen	<i>Corchorus olitorus</i>	Leaf	13.2	13.0	89.1	115.3
		Stem	26.5	9.2	94.9	130.6
		Root	23.6	10.3	92.3	126.2
		Total	63.3	32.5	276.3	372.1
	<i>Amaranthus viridis</i>	Leaf	60.2	11.3	220.4	291.9
		Stem	33.5	7.5	163.2	204.2
		Root	25.2	17.6	152.3	195.1
		Total	118.9	36.4	535.9	691.2
	<i>Celosia argentea</i>	Leaf	24.4	14.1	122.3	160.8
		Stem	18.9	11.1	122.1	152.1
		Root	2.1	2.8	38.9	43.8
		Total	45.4	28.0	283.3	356.7

### 3.1.10 Levels of Potentially Toxic Metals in Vegetables

The results of the mean values of Cu, Pb and Zn in *Amaranthus viridis*, *Celosia argentea* and *Corchorus olitorus* obtained from the study areas are presented in Table 3. The results of the potentially toxic metals samples in the vegetable parts (leaves, stem and root) revealed that among the potentially toxic metals, the order of accumulation was Zn>Pb>Cu. Studies of accumulation of heavy metals (Zn, Pb and Cd) in crops in Gaza Strip [51] and metal levels in *Cyperus malaccensis* and *Scirpus trimeter* [52] indicated that Zn had the highest values in the plants studied.

In the present study, total metal levels in plant leaves varied from 115.3  $\mu\text{g/g}$  in *Corchorus olitorus* at Bowen Agricultural Farm to 428.4  $\mu\text{g/g}$  at Feesu; total metal levels in plant stems varied from 130.6  $\mu\text{g/g}$  in *Corchorus olitorus* at Bowen Agricultural Farm to 386.8  $\mu\text{g/g}$  at Feesu; while total metal levels in plant roots varied from 43.8  $\mu\text{g/g}$  in *Celosia argentea* at Bowen Agricultural Farm to 213.2  $\mu\text{g/g}$  at Feesu. Unambiguously, all the plants' parts had their highest metal accumulation at Feesu which was an indication that Feesu had the highest metal contamination levels. For *Corchorus olitorus*, total metal distribution indicated that highest levels were mostly found in the root with the order: root > stem > leaf at both Ori-Eeru and Feesu; for *Amaranthus viridis*, total metal distribution indicated that highest levels were mostly found in the leaf with the order: leaf > stem > root at both Ori-Eeru and Bowen, while for *Celosia argentea*, total metal distribution indicated that highest levels were mostly found in the leaf with the order: leaf > stem > root at both Feesu and Bowen, indicating that accumulation of metals in plants is plant organs dependent [53].

In terms of bioaccumulation and phytoremediation potentials, *Amaranthus viridis* > *Corchorus olitorus* > *Celosia argentea* especially at Feesu and Bowen. The difference in the levels of potentially toxic metal

contamination among different vegetables is due, in part, to their morpho-physiological capabilities to retain and tolerate varying amounts of potentially toxic metals [52]. Other factors that may affect potentially toxic metals content in vegetables are metal concentrations in soils, soil pH, soil organic carbon and matter contents, types and varieties of vegetables, and plant age, but metal concentration in soil is the dominant factor [52].

According to Codex Alimentarius Commission [54], the respective safe limits of Cu, Pb and Zn in vegetables are 40.00, 5.00 and 0.60  $\mu\text{g/g}$ . The leafy parts of a given vegetable are the regularly consumed portion. In the present study, levels of Cu in the vegetable leaves ranged from 11.3  $\mu\text{g/g}$  in *Amaranthus viridis* to 21.7  $\mu\text{g/g}$  in *Corchorus olitorus* implying that the vegetables collected from the roadside soils were safe for consumption with respect to their Cu levels. However, their Pb levels ranged between 4.6  $\mu\text{g/g}$  in *Corchorus olitorus* and 60.2  $\mu\text{g/g}$  in *Amaranthus viridis*. Thus, apart from *Corchorus olitorus*, the safe consumption of other vegetables studied cannot be guaranteed in view of their Pb levels. Zinc levels in the vegetable leaves, with a range of 79.0  $\mu\text{g/g}$  in *Corchorus olitorus* to 378.1  $\mu\text{g/g}$  in *Amaranthus viridis* gave serious cause for health concern as regular consumption of such vegetables might lead to zinc-induced health infarctions. Although the levels of heavy metals in some edible parts were within the permissible level, unbridled continual consumption of vegetables grown on potentially toxic metal contaminated sites could lead to bioaccumulation and consequent adverse health effects [55, 56]. This is because such vegetables might absorb enough amounts of potentially toxic metals to become a source of potential health hazard to human [57].

Other researchers have reported that metals such as Fe, Cu, Cd, Cr, Pb, Hg and Ni have the ability to produce reactive oxygen species [58, 59] in living systems thereby leading to lipid peroxidation, DNA damage and altered calcium homeostasis. Thus, regular consumption of vegetables planted on roadside and other soils polluted by potentially toxic metals could lead to several health implications, such as, cardiovascular diseases, cancers, Alzheimer's disease, arthritis, diabetes, fatigue and memory loss [58, 59].

### 3.1.11 Correlation Analysis of Potentially Toxic Metals in the Farmland Soil

Table 4 contains the values of correlation coefficients obtained for the metals in soil samples. Significant positive correlation value ( $r = 0.661$ ) was obtained for Cu and Pb (at  $P \leq 0.05$ ), while an even higher significantly positive correlation ( $r = 0.931$ ) was obtained for Zn and Pb (at  $P \leq 0.01$ ). Obviously, Cu, Pb and Zn might have similar associations with respect to their anthropogenic or even natural sources in the soil samples studied. Besides, with the high positive correlation values exhibited by these metals, there could exist some antagonistic interaction of Pb with Cu and Zn in the performance of their biochemical roles since Pb is an outrightly toxic metals, while Cu and Zn are essential metals at low concentrations.

**Table 4** Correlation analysis of the potentially toxic metals in the soil samples

Element	Cu	Pb	Zn
Cu	1.000		
Pb	0.661*	1.000	
Zn	0.342	0.931**	1.000

\*\*Value is significant at  $P \leq 0.01$ ; \*Value is significant at  $P \leq 0.05$

### 3.1.12 Transfer Factor (TF) of Each Metal in the Plant Parts

In agreement with the findings of Zhang et al. (2011) [52], potentially toxic metal concentrations were higher in soil samples than their values in vegetable samples. This observation could be as a result of the vegetable roots acting as a barrier for translocation of metals, depending on the ionic size of elements and other biochemical and plant physiological parameters that regulate mineral uptake. Table 5 shows the transfer factor (TF) of different potentially toxic metals from soil to vegetables calculated as the ratio between the average concentrations of heavy metals in vegetables and their concentration in soil. In *Amaranthus viridis*, the order of TF was Zn > Pb > Cu; in *Celosia argentea*, the order was Zn > Cu > Pb; while the TF order in *Corchorus olitorus* was Zn > Cu > Pb. The results showed that Zn had the highest TF in the three vegetables implying that the vegetables had capacity to store Zn more than the other metals. By extension, consumers of the vegetables planted on metal-contaminated sites might experience Zn exposure more readily.

Similar results in an earlier study [52] concluded that Zn had the highest TF among other metals and the order was Zn > Cd > Ni > Pb > Co. They also reported that the high mobility of Zn with natural occurrence in the soil and the low retention of Zn in the soil than other toxic cations may elevate the TF of Zn. Results of the present study did not, however, agree expressly with the another study [55] where the highest TF of metals was for Cu and order was Cu > Co > Fe > As > Zn > Ni.

**Table 5** Transfer factor values of potentially toxic metals in vegetables

Site	Vegetable	Part	Pb	Cu	Zn
Ori-Eeru	<i>Amaranthus viridis</i>	Leaf	0.59	0.64	0.96
		Stem	0.36	0.59	1.00
		Root	0.76	0.67	1.41
	<i>Celosia argentea</i>	Leaf	0.80	0.63	0.56
		Stem	0.68	0.66	0.66
		Root	1.29	0.76	0.69
	<i>Corchorus olitorus</i>	Leaf	0.76	0.69	1.20
		Stem	0.80	0.68	1.31
		Root	0.98	0.70	1.73
Feesu	<i>Amaranthus viridis</i>	Leaf	1.67	0.82	1.04
		Stem	0.95	0.76	0.92
		Root	1.67	0.84	1.94
	<i>Celosia argentea</i>	Leaf	0.64	0.69	0.20
		Stem	0.64	0.50	0.45
		Root	1.72	0.97	1.28
	<i>Corchorus olitorus</i>	Leaf	1.74	0.67	1.35
		Stem	1.60	0.40	0.30
		Root	2.60	0.75	1.74
Bowen	<i>Amaranthus viridis</i>	Leaf	2.19	0.76	2.38
		Stem	1.45	0.65	1.99
		Root	3.41	0.79	4.30
	<i>Celosia argentea</i>	Leaf	2.15	0.67	1.35
		Stem	0.55	0.40	0.30
		Root	2.73	0.75	1.74
	<i>Corchorus olitorus</i>	Leaf	2.00	0.69	1.69
		Stem	1.79	0.66	0.94
		Root	2.52	0.71	1.90

**Table 6** Parameters used in CDI and THQ calculations of potentially toxic metals in the vegetables [25]

Parameter	Meaning	Unit	Value	
			Adult	Children
AT	Average exposure time	d	365	365
BW	Body weight	kg	70	15
EF	Exposure frequency	d/yr	350	350
ED	Exposure duration	years	24	6
IF	Intake factor	unitless	-	-
IN	Inhalation rate	m <sup>3</sup> /day	20	20
Rfd	Reference dose	mg/kg-d	Rfd(Pb)=0.3 Rfd(Cu)=0.04 Rfd(Zn)=0.02	-
IR	Ingestion rate(soil)	kg/day	0.0001	0.0002
	Daily intake (vegetable)	g/person/d	400	400
Cs	Concentration of metals	mg/kg	-	-

**Table 7** Carcinogenic and non-carcinogenic health risks of metals in farmland soils

Site	Human Classification	CDI Non-Carcinogenic			CDI Carcinogenic		
		Adult x 10 <sup>6</sup>			Pb	Cu	Zn
		Pb	Cu	Zn			
Ori-Eeru	Adult	30.9	22.5	70.3	0.003	0.002	0.006
	Child	28.8	20.9	65.6			
Feesu	Adult	26.6	13.7	102	0.002	0.001	0.009
	Child	24.4	12.8	95.1			
Bowen	Adult	7.7	5.7	51.9	0.0007	0.0005	0.005
	Child	7.2	5.3	48.4			

### 3.1.13 Health Risk Assessment of Potentially Toxic Metals in the Farmland Soil

Plain data on metal content of soil are not always sufficient to evaluate the risk that arises from the exposure of human (adult and children) to different potentially toxic metals in soils [25], especially when more concise details on human health risk are required. Exposure of human to soil is essentially through inhalation of dust, ingestion of dust-bearing materials including food (oral exposure) and direct body contact with soil particles in work place, or during games. Risk characterization relevant for the present study comprises of calculations of carcinogenic and non-carcinogenic risks for ingestion of soil.

Parameters used for the various risk characterization determined are contained in Table 6, while Table 7 presents the carcinogenic and non-carcinogenic health risks of metals in farmland soils. The chronic daily intake for soil ingestion indicated that the level of human health risk caused by non-carcinogenic pollutants in children ( $\times 10^6$  mg/kg/day) were 7.15–28.8 for Pb; 5.27–20.9 for Cu; and 48.4–95.1 for Zn. Similarly, the level of human health risk caused by non-carcinogenic pollutants in adults

( $\times 10^6$  mg/kg/day) had the following ranges: Pb (7.67–30.9); Cu (5.65–22.5); Zn (51.9–102); and Fe (1120–1300). The implication of these values is that deaths that could be attributed to the non-carcinogenic risks of the pollutants in each million are very low in these metals, hence the risk is of minimal level. Furthermore, the CDI values for non-carcinogenic (oral) exposure in children were much lower than the values obtained for adults. This also suggests that the adult who engaged in farming activities on the soils of the sites studied were more vulnerable to metal-induced hazards than children.

The chronic daily intake (CDI) considered to be carcinogenic (in children) for the farmland soils (Table 7) gave a range of 5.3 for Cu to 95.1 for Zn, while for adults, the range was 5.7 in Cu to 102.0 in Zn. The CDI (mg/kg/day) for Pb ranged from 0.0007 to 0.003; Cu ranged from 0.0005 to 0.002; and Zn ranged from 0.005 to 0.009. There was no minimal risk level (MRL) specification for Pb. However, values for both Cu and Zn fell below the minimal risk level (oral) of 0.1 and 0.3 mg/kg/day, respectively. Risk Assessment Information System (RAIS) gave oral chronic reference dose of 0.04 and 0.02 mg/kg/day for Cu and Zn, respectively [25]. The implication was that oral exposure to the soil from these farmlands does not pose adverse cancer health effects to the inhabitants of these areas.

### 3.1.14 Potential Health Risk Associated with Consumption of Vegetables

The potential health risks were assessed using target hazard quotient (THQ), which was calculated as stipulated by USEPA (2002) [26]. The parameters used in the equation are listed in Table 6. The potential health risk to local residents associated with vegetable consumption was assessed with THQ index (Table 8). Of all the three vegetables, *Amaranthus viridis* obtained from Ori-Eeru had the lowest THQs. For both children and adults, the THQs of potentially toxic metals in the three vegetables were above 1.0, indicating that regular consumption of these vegetables might constitute a significant health risk to consumers over a prolonged period of time. The mean THQ of the three potentially toxic metals for both adult and children was in the order: Zn > Cu > Pb.

**Table 8** Target hazard quotient (THQ) values of the potentially toxic metals via vegetable consumption

Site	Vegetable	Human class	Pb	Cu	Zn	Total THQ
Ori-Eeru	<i>Corchorus olitorus</i>	Adult	15	57	788	860
		Child	17	67	917	1001
		Adult	13	62	756	831
Feesu	<i>Celosia argentea</i>	Child	16	73	882	971
		Adult	11	38	349	398
	<i>Amaranthus viridis</i>	Child	13	45	407	465
		Adult	15	81	2050	2146
	<i>Corchorus olitorus</i>	Child	17	95	2390	2502
		Adult	8	41	1670	1719
Bowen	<i>Celosia argentea</i>	Child	9	48	1940	1997
		Adult	16	56	2300	2317
		Child	19	65	2690	2772
	<i>Corchorus olitorus</i>	Adult	9	36	605	650
		Child	11	42	706	759
		Adult	7	31	619	657
	<i>Amaranthus viridis</i>	Child	8	36	723	767
		Adult	18	40	1170	1228
		Child	21	47	1370	1438
Mean THQ of vegetables		Adult	12±4	49±16	1150±700	1200±700
		Child	15±5	37±19	1340±820	1410±830

## 4. Conclusion

This study investigated the physicochemical characteristics of soil and health risk assessment of potentially toxic metals in soil and vegetables from roadside farmlands in Iwo, Southwestern Nigeria. Findings emanated from the study indicated that levels of  $PO_4^{3-}$  in the soil samples were higher than the recommended environmental levels of  $PO_4^{3-}$  in soil that could satisfactorily support planting of vegetables for commercial and consumption purposes. Also, the potentially toxic metal concentrations determined in the three green vegetables indicated greatest accumulation in *Amaranthus viridis*. Copper and zinc in the edible parts of the vegetables occurred at levels lower than the maximum allowable limit of the WHO standards, while Pb levels were above the WHO permissible levels, and this gave some cause for concern. The lower than WHO permissible levels of Cu and Zn, however, could not altogether guarantee the consumption safety of the vegetables on a long-term basis as indicated by the target hazard quotient values. It is recommended that in order to minimize exposure of people living around road side farmlands to metal-induced health problems, consumption of vegetables grown on such farmland soils should be done with caution.

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