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Elemental Compositions of Tropical Vegetables and Soils in Edo State, Nigeria Using X-ray Fluorescence Technique

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Authors' contributions

This work was carried out in collaboration among all authors. Author AOO collected the samples, carried out the investigation, performed the statistical analysis and wrote the first draft of the manuscript. Author MBO designed the study as the research supervisor. Author AAO managed the literature survey. All the authors read and approved the final manuscript before submission for publication.

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ABSTRACT

Aim: This research work investigated the bioaccumulation of metals in selected edible vegetables from the soils on which they were grown.

Place of Study: Two (2) different study locations were chosen from Etsako-West Local Government Areas of Edo State of the Federal Republic of Nigeria. Etsako-West Local Government Area has an area of 660 km² on Latitude 7.0878ºN and Longitude 6.5010ºE with the headquarters in Auchi.

Methodology: Leaves of fluted pumpkin (*Telfairia occidentalis*), African spinach (*Amaranthus hybridus*) and water leaf (*Talinum triangulare*) and soil samples were randomly collected from Water Board and Iyerekhu farms in Etsako-West Local Government Area, Edo State, Nigeria and were analysed for their elemental compositions, using X-ray fluorescence (XRF) technique.

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Results: In both soil and plant samples, silicon (Si) were most abundant, ranging between 18.85 and 38.91%. The decreasing order of abundance of elements in the plant samples was Si>K>Ca>Al>Cl>S>P>Mg>Fe>Ti>Mn>Zn>Sr>Cr. Toxic heavy metals such as As, Pb, Co, Cd and Cu were not detected in both soil and vegetable samples. The concentrations of the elements in the samples were higher than the permissible limits of WHO/FAO and EU for soils and plants, except Zn in the soil samples and *Talinum triangulare* from Iyerekhu farm. The peak transfer factor, 238.43 was obtained for K in *Talinum triangulare* from Iyerekhu farm while the least is 0.00 for Zn in all the plant samples. The overall mean ability of plant to absorb elements from the soil was most with *Talinum triangulare*, followed by *Amaranthus hybridus.*

Conclusion: The vegetables studied had high tendency to bioaccumulate the bioavailable metals in soils. However, all the vegetables studied, especially *T. triangulare* could be used in phytoremediation of polluted soils.

Keywords: X-ray fluorescence; heavy metals; transfer factor; phytoremediation.

ABBREVIATIONS

XRF	*: X-ray Fluorescence*
EDXRF	*: Energy-Dispersive X-ray Fluorescence*
WB	*: Soil sample from Water Board*
IY	*: Soil sample from Iyerekhu*
WB_1	*: Telfaira occidentalis from Water-Board*
WB_2	*: Amaranthum hybridus from Water-Board*
WB_3	*: Talinum triangulare from Water-Board*
IY_1	*: Telfaira occidentalis from Iyerekhu*
IY_2	*: Amaranthum hybridus from Iyerekhu*
IY_3	*: Talinum triangulare from Iyerekhu*
BDL	*: Below Detection Limit*

1. INTRODUCTION

Minerals are very important ingredients for normal metabolic activities of body tissues. Out of ninety-two (92) naturally occurring minerals, twenty-five (25) are present in living organisms. They are constituents of bones, teeth, blood, muscles, hair and nerve cells. Vitamins cannot be properly assimilated without the correct balance of minerals [1].

Among the plants, vegetables are excellent sources of minerals and contribute to recommended dietary allowance (RDA) of these essential nutrients, forming an important part of a human beings diet with marked health effects [2]. They are valued mainly for their high carbohydrate, vitamins and mineral contents. They are classified as edible roots, stems, leaves, fruits or seeds.

Fluted Pumpkin (*Telfairia occidentalis*) is a species of cucurbitaceace family [3], largely consumed as soup and medicine in West Africa, especially the southern Nigeria. It versatility across different ethnic groups has earned it different names such as “iroko” (or “apiroko”) in Yoruba, “ugu” in Igbo, “ubong” in Efik, and “umeke” in Edo. It grows with the tendency of creeping from its root across the ground, forming long twisting tendrils, which can be properly controlled to give beauty and shade. The sights of it in residences in the southern Nigeria show how significant it is to human health. Fluted pumpkin has been identified as a good source of protein, oil, minerals, and vitamins, but low crude fibre [4].

African spinach (*Amaranthus hybridus*), usually called “green vegetable” is an annual herbaceous plant, characterized with greenish small flowers, growing up to 1-6 feet high. When fresh, the taproot is reddish pink. Besides using the leaves to prepare soup [5], large amount of squalene has been obtained from *Amaranthus hybridus* [6].

Waterleaf (*Talinum triangulare*) is a cosmopolitan non-conventional vegetable crop of the *portulacaceae* family, which is native to Africa and widely grown in West Africa, Asia, and South America [7]. It is highly adapted to hot and humid climate, and poor quality soil [8], thriving and growing in large quantity in waste places and farmlands. However, it is underrated and underutilized in Nigeria. Some of its common names are “gbure” in Yoruba, “gbolodi” in Igbo, “ebe-dondon” in Edo. In spite of its demean value, *Talinum triangulare* has high moisture content, iron, thiamine, vitamins C and E, omega-3 fatty acids and minerals [9].

The use of X-ray Fluorescence (XRF) technique for elemental determination of inorganic and organic samples is gradually being preferred to other analytical methods, because the former involves non-destructive analysis, minimal or no sample preparation, simultaneous multi-element analysis, use of no noxious chemicals and production of no toxic wastes, avoidance of losses encountered in chemical methods during dry ashing and acid extractions and analysis performed on a wide range of sample types such as solids, liquids, powders, pastes, films from ppm to high percentage. Since XRF signal is obtained from transitions among inner shell electrons, not bonding electrons, XRF also has the advantage that signals are independent of chemical form. As a result of its proficiency, XRF can detect elements such as Na, Mg, P, S, Cl, K, Ca only at higher concentrations or under highly specialized conditions, and heavier elements namely Mn, Fe, Cu and Zn (trace metals) or toxic heavy metals are readily analyzed, even at trace levels. An exception is in the detection of lightest element (e.g. H, B, C, N, O), which exist in biological samples [10].

This present research work is aimed at using X-ray Fluorescence (XRF) technique to investigate: (i) the elemental compositions and (ii) transfer factors between the vegetables of fluted pumpkin (*Telfairia occidentalis*), African spinach (*Amaranthus hybridus*) and water leaf (*Talinum triangulare*) and the soil on which they are grown.

2. MATERIALS AND METHODS

2.1 Study Locations

Two (2) different study locations were chosen from Etsako-West Local Government Areas of Edo State of the Federal Republic of Nigeria. Etsako-West Local Government Area has an area of 660 km² on Latitude 7.0878ºN and Longitude 6.5010ºE with the headquarters in Auchi, comprising Auchi, Uzairue, South Ibie, Agbede and the Anwain Clan (Fig. 1). The population grew to 42,638 by 1952, including people from many Nigerian tribes and as of 2005–2006, the population was 152,652. The locations in Etsako-West Local Government Area were Water-Board, Auchi and Iyerekhu, South-Ibie, Edo State. The farmland in Water-Board, called Peter Farm was located on a slope of a hill, flanked with River Orle, running through Warrake and Iyamho. The farmland in Iyerekhu, called Oloyede-Ogunbodede Farm was a piece out of many farmlands in the location without any sight of water body or refuse disposal site. Majority were into sustenance farming with the use of fertilizers to enhance the soil fertility.

2.2 Sample Collection

Random sampling technique was employed to collect the vegetable samples of fluted pumpkin leaves (*Telfairia occidentalis*), African spinach, "Green" (*Amaranthus hybridus*) and waterleaf (*Talinum triangulare*) from the two study locations to obtain composite samples. The leaves of vegetable samples were separated from the whole plants with the aid of hand gloves and a stainless steel knife and were carefully packaged in polythene bags and labelled. Similarly, random samples of soils from the study locations were taken at uniform depth of 15 cm

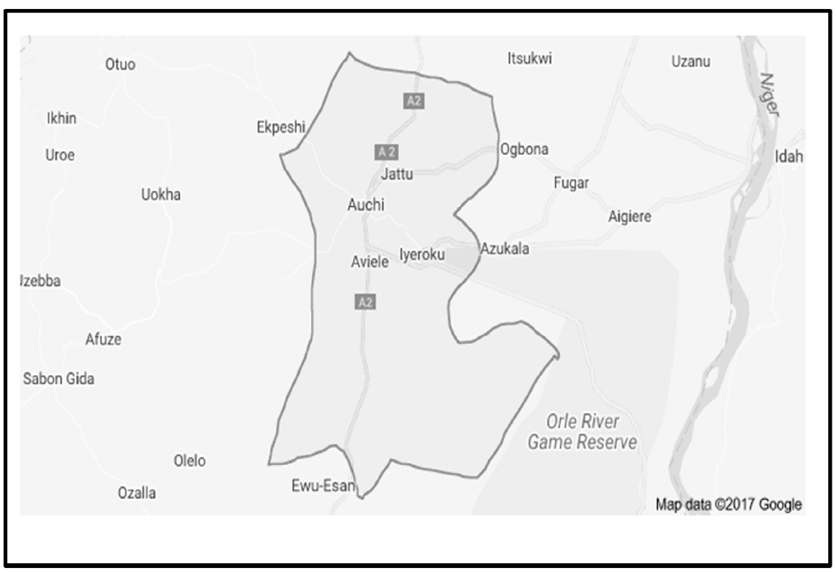

Fig. 1. Map of Edo State showing Etsako-West Local Government Area (Source: [11])

with the aid of a hand trowel that had been pre-cleaned with concentrated nitric acid in order to prevent heavy metal contamination prior to analysis.

2.3 Preparation of Vegetable Samples

The vegetable samples were washed with tap water and de-ionized water to remove air pollutants, followed by oven drying at 105ºC 48 h to remove moisture. The dried samples were pulverized, using agate pestle and mortar, followed by sieving through a 0.5 mm mesh size sieve to obtain a uniform particle size. Each vegetable sample was labelled and stored in a dry plastic container that had been pre-cleaned with concentrated nitric acid to prevent heavy metal contamination prior to analysis with X-ray fluorescence (XRF) spectrometer.

2.4 Preparation of Soil Samples

The soil samples were air dried for 48 hours, ground and sieved using 0.5 mm mesh size sieve to have uniform particle size. Each sample was labelled and stored in a dry plastic container that had been pre-cleaned with concentrated nitric acid prior to analysis with X-ray fluorescence (XRF) spectrometer.

2.5 Determination of Elemental Compositions

Experimental studies of both soil and vegetable samples were carried out at Ahmadu Bello University, Department of Chemical Engineering, Zaria, Nigeria, using an Energy-Dispersive X-ray Fluorescence (EDXRF) spectrometer (Oxford Instrument, Supreme X8000) and method described elsewhere was adopted with some modifications [12]. Samples were oven-dried at 80ºC for 18-20 h. Each sample was repeatedly fine-ground to less than 50 μm sieve-size, weighed to between 100-200 mg from which pellets of 2.5 cm diameter were made in a pellet-pressing machine under 10-15 ton of pressure. The samples were irradiated for 1400 s under vacuum using EDXRF Supreme X8000. The samples were irradiated using an Rh X-ray tube operated at 15 kV (Na to Sc) and 50 kV (Ti to U). The current was automatically adjusted (max. of 1 mA). A 10 mm collimator was chosen. The detection was carried out using the Si (Li) detector cooled with liquid nitrogen. The intensity of element, Kα counts per second (cps/μA) was obtained from the sample X-ray spectrum, using EDX Supreme X8000 software package.

2.6 Transfer Factor (TF)

Transfer factor, a measure of the bioavailability of an element at a particular position on a species of plant, was calculated by dividing the concentration of metal in the plant by the elemental concentration in soil [13,14].

3. RESULTS AND DISCUSSION

3.1 Elemental Compositions

Table 1 depicts the elemental compositions of the soil and vegetable samples obtained from the two study locations in Etsako-West LGA, Edo State. From the results, the most abundant element is silicon (Si) with its concentration in the soil samples almost twice in the vegetable samples. The soil sample from Water Board farm is lower in Si concentration than that of Iyerekhu farm.

In addition, the results also reveal that magnesium (Mg), calcium (Ca), phosphorus (P), potassium (K), sulphur (S) and chlorine (Cl) in the plant samples are higher in concentrations than their corresponding soils samples whereas an opposite trend is observed for silicon (Si) (Fig. 2).

Silicon, the most abundant element in both soil and plant samples, is found at its peak concentration, 25.97±0.10% in *Talinum triangulare* from Water Board farm, which is followed by another high value, 24.46±0.12% in *Telfairia occidentalis* obtained from Iyerekhu farm. This observation may account for the varying abilities of different plants to absorb elements from the soil, which account for the bioaccumulation of minerals in their tissues. Silicon plays a dual role of preventing porous bones, called osteoporosis [15] and preventing hardening and narrowing of arteries, called athecoscelosis due to Al toxicity by shielding Al [16]. Silicon daily uptake is between 20 to 50 mg. Monocotyledons such as cereals, herbaceous plants and grasses are usually termed Si accumulators.

Potassium, which is the second most abundant element, is found at 16.69±0.11% in *Talinum triangulare* from Iyerekhu farm, which is higher than the concentrations obtained in the soil samples. K enhances iron activity and controls hypertension.

From the two study locations, Ca is most prominent in *Aramanthus hybridus* (green vegetable or African Spinach), exhibiting higher value of 10.32±0.06% in the plant obtained from Water Board farm than 8.88±0.04% observed in the same plant from Iyerekhu. The studied *Aramanthus hybridus* is a good source of calcium to both animals and humans, which can help in bones, nerves and muscles development as well as monitoring the nutrients passage, blood clotting and insomnia [17].

Similar to high concentrations of silicon, chlorine concentrations are found at varying peaks in different plant samples at different study locations. A peak concentration of Cl, 6.21±0.02% is observed in *Amaranthus hybridus* from Water Board farm, which is higher than 5.84±0.01% observed in *Talinum triangulare* from Iyerekhu farm.

There are also different peak concentrations of sulphur observed for the various vegetable samples obtained from the two study locations. The highest concentration of sulphur, 4.19±0.0.3% is observed in *Telfairia occidentalis* from Water Board farm, which is followed by 3.32±0.02% observed in *Talinum triangulare* from Iyerekhu.

The peak phosphorus concentration, 2.86±0.01% is observed in *Telfairia occidentalis* (pumpkin leaves) from Water Board farm, which is much higher than 2.08±0.01% observed in pumpkin from Iyerekhu farm. The physiological buffer of humans is monitored by the conjugate base and acid of phosphates [17].

The peak magnesium concentration, 2.26±0.01% is obtained in *Talinum triangulare* (water leaves) from Iyerekhu farm, which is much higher than the value, 1.81±0.01% obtained for the same botanical plant from Water Board farm. This observation confirms that the same plant behaves differently on different soils and climatic conditions. Mg serves as a co-factor in many enzymes for protein synthesis, which is used to monitor hypertension and diabetes [18,19].

While the soil and plant samples possess trace elements, which include chromium (Cr), zinc (Zn), manganese (Mn), iron (Fe), titanium (Ti), strontium (Sr) and aluminium (Al), toxic heavy metals like mercury (Hg), cadmium (Cd), arsenic (As), lead (Pb) are not detected in the samples used for this research (Table 1). Generally, the concentrations of Al, Fe and Ti are higher in the soil samples than the plant samples from the two locations whereas an opposite trend is observed in terms of Cr, Zn, Mn and Sr.

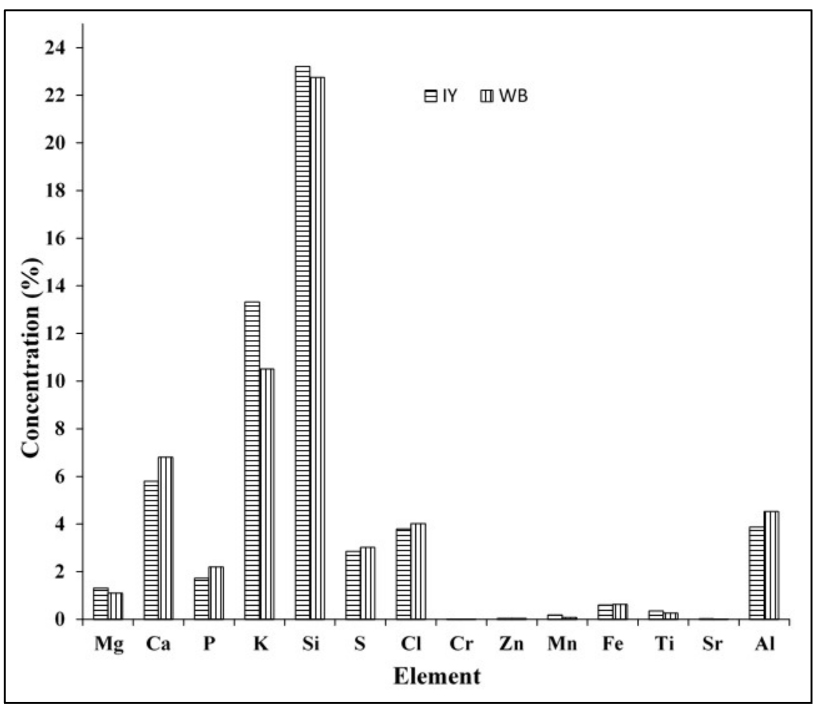

Fig. 2. Mean concentrations of elements in vegetable samples from Water-Board (WB) and Iyerekhu (IY) Farms

Table 1. Elemental compositions of soil and vegetable samples from Water-Board and Iyerekhu Farms, Etsako-West Local Government Area

Sample		**Mineral (%)**						
		Mg	**Ca**	**P**	**K**	**Si**	**S**	**Cl**
Soil	WB	0.30±0.01^{a}	0.10±0.01^{b}	0.20±0.01^{b}	0.30±0.01^{a}	37.38±0.23^{b}	0.25±0.05^{b}	0.04±0.01^{b}
	IY	0.16±0.01^{b}	0.16±0.01^{a}	0.25±0.02^{a}	0.07±0.00^{b}	38.91±0.10^{a}	0.32±0.01^{a}	0.05±0.00^{a}
Vegetable	WB$_1$	0.85±0.01^{c}	7.25±0.02^{c}	2.86±0.01^{a}	13.00±0.03^{b}	18.85±0.10^{f}	4.19±0.03^{a}	6.21±0.02^{a}
	IY$_1$	0.80±0.01^{d}	5.42±0.02^{d}	2.08±0.01^{b}	12.00±0.05^{c}	24.46±0.04^{b}	3.11±0.02^{c}	3.90±0.03^{c}
	WB$_2$	0.61±0.01^{e}	10.32±0.06^{a}	0.88±0.01^{e}	9.42±0.10^{e}	23.40±0.02^{d}	1.94±0.01^{f}	2.08±0.01^{e}
	IY$_2$	0.86±0.01^{c}	8.88±0.04^{b}	1.31±0.01^{d}	11.27±0.05^{d}	24.31±0.12^{c}	2.11±0.01^{e}	1.63±0.01^{f}
	WB$_3$	1.81±0.01^{b}	2.86±0.01^{f}	2.85±0.01^{a}	9.10±0.10^{f}	25.97±0.10^{a}	2.93±0.01^{d}	3.77±0.02^{d}
	IY$_3$	2.26±0.01^{a}	3.11±0.02^{e}	1.77±0.01^{c}	16.69±0.11^{a}	20.33±0.50^{e}	3.32±0.02^{b}	5.84±0.01^{b}
Mean (Vegetable)		**1.20±0.01**	**6.31±0.03**	**1.96±0.01**	**11.91±0.07**	**19.50±1.01**	**2.93±0.07**	**3.91±0.06**

Sample		**Mineral (%)**						
		Cr	**Zn**	**Mn**	**Fe**	**Ti**	**Sr**	**Al**
Soil	WB	0.006±0.001^{a}	BDL	0.01±0.00^{b}	2.32±0.01^{a}	0.96±0.01^{b}	0.01±0.00^{b}	6.83±0.02^{a}
	IY	0.005±0.000^{b}	BDL	0.08±0.01^{a}	2.21±0.01^{b}	1.36±0.01^{a}	0.02±0.00^{a}	4.83±0.01^{b}
Vegetable	WB$_1$	0.012±0.000^{e}	0.04±0.00^{c}	0.10±0.00^{c}	0.24±0.00^{f}	0.06±0.00^{f}	0.01±0.00^{c}	3.52±0.01^{f}
	IY$_1$	0.016±0.000^{c}	0.08±0.01^{a}	0.16±0.01^{b}	0.73±0.01^{c}	0.31±0.01^{c}	0.02±0.00^{b}	3.10±0.01^{e}
	WB$_2$	0.082±0.001^{a}	0.04±0.01^{c}	0.05±0.00^{d}	1.17±0.01^{a}	0.57±0.01^{b}	0.04±0.00^{a}	6.01±0.01^{a}
	IY$_2$	0.006±0.000^{f}	0.05±0.00^{b}	0.10±0.00^{c}	0.86±0.00^{b}	0.60±0.02^{a}	0.04±0.00^{a}	4.30±0.01^{b}
	WB$_3$	0.014±0.001^{d}	0.05±0.00^{b}	0.10±0.00^{c}	0.47±0.01^{d}	0.17±0.01^{d}	0.02±0.00^{b}	4.03±0.01^{d}
	IY$_3$	0.028±0.000^{b}	BDL	0.28±0.01^{a}	0.26±0.00^{e}	0.13±0.00^{e}	0.02±0.00^{b}	4.24±0.01^{c}
Mean (Vegetable)		**0.026±0.001**	**0.05±0.01**	**0.13±0.02**	**0.62±0.02**	**0.31±0.03**	**0.03±0.00**	**4.20±0.02**

WB = soil sample from Water Board; IY = soil sample from Iyerekhu; WB$_1$ = Telfaira occidentalis from Water-Board; WB$_2$ = Amaranthum hybridus from Water-Board; WB$_3$ = Talinum triangulare from Water-Board; IY$_1$ = Telfaira occidentalis from Iyerekhu; IY$_2$ = Amaranthum hybridus from Iyerekhu; IY$_3$ = Talinum triangulare from Iyerekhu; BDL = Below Detection Limit; Results are expressed as means±standard deviations ($n = 3$). Values in the same column of the same sample type with the same superscript letters are not significantly different ($p < 0.05$)

The aluminium concentration is conspicuously highest in *Amaranthum hybridus* from Water Board farm. The next high concentration, 4.30% is observed in the same plant from Iyerekhu farm. The adverse effect of Al on hardening and narrowing of arteries has been reported to being checked by high concentration of silicon [16].

The Fe concentration is most abundant at 1.17±0.01% in *Amaranthus hybridus* from Water Board farm, followed by 0.86±0.00% in same plant from Iyerekhu farm. Fe in the body is responsible for the formation of blood and transfer of oxygen and carbon (IV) oxide from one tissue to another [20]. It is the most abundant and an essential constituent for all plants and animals. However, at high concentration, Fe causes tissues damage and some other diseases in humans such as anaemia and neurodegenerative condition [21]. The Fe contents of the vegetable samples and the soils on which they grow are higher than the WHO/FAO safe limit of 0.04% [22].

Among all the plant samples, the peak titanium concentration is obtained in *Amaranthus hybridus*, which is relatively affected by difference in locations. The specific biochemical activities of Ti in human are still not known, except its use in the manufacturing of medical instruments.

The concentration of manganese is at its peak (0.28±0.01%) in *Talinum triangulare* from Iyerekhu farm, which is quite higher than its value (0.10±0.00%) in the same plant from Water Board. Manganese toxicity is a relatively common problem compared to other micronutrient toxicity. It is usually associated with soils of pH 5.5-6.0 with possible symptoms, which include chlorosis and necrotic lesions on old leaves, dark brown or red necrotic spots, and accumulation of small particles of MnO_2 in epidermal cells of leaves or stems, often referred to as "measles", drying leaf tips, and stunted roots [23].

The Zn concentration is 0.05–0.08% in the plant samples while the concentrations in the soil samples are below the detection limits. Zn concentrations in the range of 150–300 mg/kg (0.015-0.030%) have been measured in polluted soils [24]. High levels of Zn in soil inhibit many plant metabolic functions, stunted growth of both root and shoot [25]. The Zn concentrations in this study exceed the permissible limits of 60 mg/kg (0.006%) [26]. While the recommended dietary allowance for Zn is 15 mg/day for men and 12 mg/day for women, high concentration of Zn in vegetables may cause vomiting, renal damage, cramps, etc [27].

Amaranthus hybridus exhibits the highest concentration of Sr with value 0.04±0.00% for the plant samples from both Water Board and Iyerekhu farms. Strontium (Sr), although considered as a food contaminant, currently has no known biological role [27]. The effect of strontium on bone is likely related to its similarity to calcium, a mineral with a known biological value. The average daily intake of strontium from the diet is estimated at only 1 to 5 mg/kg [28].

The peak concentration of Cr is 0.082±0.001% in *Amaranthus hybridus* from Water Board farm and is 0.028±0.000% in *Talinum triangulare* from Iyerekhu farm. The EU Standards for the metal in soils and vegetables are 150 and 0.3 mg/kg, respectively [29]. All the samples (soils and vegetables) investigated in this study exceed the EU permissible limits for Cr.

3.2 Inter-elements Correlation

Table 2 shows the inter-elements Pearson's Correlations ($p<0.05$, 0.01) of the available elements in both soil and vegetable samples obtained from the two study locations in Etsako-West LGA, Edo State. The negative r values imply no correlation while the positive values imply correlation between the elements at the specified significant levels of either $p<0.01$ or $p<0.05$.

From Table 2, Mg is significantly correlated with P, K, S and Cl ($p<0.05$); P is significantly correlated with K, S and Cl ($p<0.05$); K is significantly correlated with S and Cl ($p<0.05$); S with Cl ($p<0.01$); Cr with Mn ($p<0.01$); Zn with Fe and Ti ($p<0.05$); Fe with Ti, Sr ($p<0.01$) and Al ($p<0.05$); Ti with Sr ($p<0.01$) and Al ($p<0.05$); and Sr with Al ($p<0.05$). However, Si is not significantly correlated with any element found in both soil and plant samples from the two study locations.

3.3 Transfer Factor

Table 3 shows the transfer (or uptake) factor of all the vegetable samples relative to their soils. All the vegetable samples show appreciably high transfer factors. *Telfaira occidentalis* from Water-

Board exhibits peak transfer factors in terms of P, K, S, Cl and Mn, *Amaranthum hybridus* from Water-Board exhibits peak transfer factors in terms of Ca, Cr, Fe, Ti, Sr and Al, and *Talinum triangulare* from Water-Board possesses peak transfer factors in terms of Mg, Si and Mn. Similarly, *Telfaira occidentalis* from Iyerekhu farm shows peak transfer factors in terms of P and Si, *Amaranthum hybridus* from Iyerekhu farm shows peak transfer factors in terms of Ca, Fe, Ti, Sr and Al, and *Talinum triangulare* from Iyerekhu farm possesses peak transfer factors in terms of Mg, K, S, Cl Cr and Mn.

Generally, transfer factor expresses the bioavailability of a metal at a particular position on a species of plant and it is calculated by dividing the concentration of metal in the vegetable by the metal concentration in soil [13,14]. All the samples have significant differences in the transfer factors of metals relative to the availability of same metals in the soil (Table 3). When transfer factor is less than one, it may be a probability that soil is the main source of metal bioaccumulation in plants. However, it is more revealing that, when the value is higher than one, the total concentrations of metals in soil do not necessarily correspond to the metal bioavailability in plants. The bioavailability of heavy metals depends on a number of physicochemical properties such as pH, organic matter contents, cation exchange capacity, redox potential, soil texture and clay contents [30]. This present study reveals that the same species of vegetable from different locations behaves differently in terms of absorption of elements from the soil. This variation may be adduced, among other things, to different botanical sources and environments.

The peak transfer factor (238.43) is obtained for K in *Talinum triangulare* from Iyerekhu farm while the least is 0.00 for Zn in all the vegetable samples. The absorption of zinc (Zn) is completely null for all the plants samples obtained from the two study locations, implying that zinc is not bioavailable in their soil samples. Surprisingly, Si, which is the most abundant metal in both soil and vegetable samples, has transfer factor lower than one.

From the two study locations, it is worthy of note that of the vegetable samples used in this research, the overall mean ability of plant to absorb elements from the soil lies most with *Talinum triangulare*, more with *Amaranthus hybridus* and less with *Telfairia occidentalis*. High transfer factors of heavy metals for *Talinum triangulare* and *Amaranthus hybridus* and low transfer factor for *Telfairia occidentalis* have been reported [31]. Higher transfer coefficients reflect high soil contents or greater potentials of plants to absorb metals and bio-accumulate into tissues [32]. However, low transfer coefficients have been reported to indicate strong sorption of the metals to soil colloids [13].

Table 2. Inter-elements pearson correlation coefficients among the vegetable samples*

Element	**Element**						
	Mg	**Ca**	**P**	**K**	**Si**	**S**	**Cl**
Mg	1.000	-0.678	0.307	0.496	-0.031	0.272	0.476
Ca		1.000	-0.331	-0.304	-0.287	-0.125	-0.127
P			1.000	0.061	-0.167	0.804	0.666
K				1.000	-0.680	0.545	0.697
Si					1.000	-0.670	-0.723
S						1.000	0.945**
Cl							1.000
Element	**Element**						
	Cr	**Zn**	**Mn**	**Fe**	**Ti**	**Sr**	**Al**
Cr	1.000	-0.549	0.942**	-0.664	-0.655	-0.539	-0.315
Zn		1.000	-0.502	0.377	0.250	-0.016	-0.409
Mn			1.000	-0.598	-0.485	-0.409	-0.385
Fe				1.000	0.930**	0.858**	0.627
Ti					1.000	0.945**	0.586
Sr						1.000	0.759
Al							1.000

**Correlation is significant at the P = 0.05 level (2-tailed); **Correlation is significant at the P < 0.01 level (2-tailed); N = 6*

Table 3. Transfer factor of the vegetable samples

Element	Transfer factor*					
	WB_1	WB_2	WB_3	IY_1	IY_2	IY_3
Mg	2.83	2.03	6.03	5.00	5.38	14.13
Ca	72.50	103.20	28.60	33.88	55.50	19.44
P	14.30	4.40	14.25	8.32	5.24	7.08
K	43.33	31.40	30.33	171.43	161.00	238.43
Si	0.50	0.63	0.69	0.63	0.62	0.52
S	16.76	7.76	11.72	9.72	6.59	10.38
Cl	155.25	52.00	94.25	78.00	32.60	116.80
Cr	2.00	13.67	2.33	3.20	1.00	4.67
Zn	0.00	0.00	0.00	0.00	0.00	0.00
Mn	10.00	5.00	10.00	2.00	1.25	3.50
Fe	0.10	0.50	0.20	0.33	0.39	0.12
Ti	0.06	0.59	0.18	0.23	0.44	0.10
Sr	1.00	4.00	2.00	1.00	2.00	1.00
Al	0.52	0.88	0.59	0.64	0.89	0.88

WB_1 = Telfaira occidentalis from Water-Board; WB_2 = Amaranthum hybridus from Water-Board; WB_3 = Talinum triangulare from Water-Board; IY_1 = Telfaira occidentalis from Iyerekhu; IY_2 = Amaranthum hybridus from Iyerekhu; IY_3 = Talinum triangulare from Iyerekhu *Transfer factor = $\frac{concentration\ of\ metal\ in\ plant}{concentration\ of\ metal\ in\ soil}$

4. CONCLUSION

The elemental compositions, void of Hg, Cd, As, Pb, are obtained at varying concentrations for soil and vegetable samples, using X-ray Fluorescence (XRF) technique. The most abundant element in both soil and vegetable samples is silicon with higher concentrations in the former than the latter. All the elements are quite higher in concentrations than the permissible limits of WHO/FAO for soils and vegetables, except for Zn in the soil samples and in *Talinum triangulare* from Iyerekhu farm. The overall mean ability of plant to absorb elements from the soil lies most with *Talinum triangulare*, more with *Amaranthus hybridus* and less with *Telfairia occidentalis*. This suggests that the absorption and retention of metals by the tissues of *Talinum triangulare* are very high, and that bioaccumulation of metals in plants is, sometimes, independent of their bioavailability in the soil. The vegetables studied in this research work, especially *T. triangulare* could be used for phytoremediation of polluted soils.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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