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Proximate Compositions and Health Risk Evaluation of Heavy Metal Uptake by Vegetables Grown at a Waste –Water Irrigated Site in Fct, Abuja, Nigeria

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ABSTRACT

The purpose of the study was to evaluate some proximate compositions and health risk of heavy metal uptake by vegetables grown at a waste-water irrigated sites in FCT, Abuja. The study was carried in dry seasons between 2015 and 2017. Two different types of vegetable samples (Lagos Spinach- Celosia argentea and African Egg-plant- Solanum macrocarpon) were collected simultaneously from three irrigated farm sites. Heavy metal levels were quantified using Atomic Absorption Spectrophotometer (AAS). Other parameters were determined using standard methods. The levels of heavy metals in vegetables varied according to sites. Proximate composition in both vegetable leaves recorded higher mean values for total ash (8.65-8.97), crude fibre (10.83-11.25), protein (4.96-5.08), Fat (3.05-3.29) and dry matter (65.58-68.85) indicating that they were rich in nutrients that promote healthy living. The mean levels of Zn (3.36±0.50) and Ni (0.03±0.01) in Lagos Spinach ; and Zn (2.80±0.36) and Ni (0.04±0.02) in African Egg-plant were generally lower than the FAO/WHO permissible limits except for Fe (14.96±0.86), (15.81±0.89) and Pb (1.12±0.11), (1.31±0.11) in both vegetables that were significantly higher ($P<0.05$) . Lagos Spinach recorded lower Metal Pollution Index (10.35) while African Egg-plant had the highest value (12.18) suggesting that these vegetables may present more health risk to the consumers of these vegetable. Daily Intake values of Fe (0.089), Zn (0.020), Ni (0.001) and Pb (0.006) in Lagos Spinach and Fe (0.094), Zn (0.017), Ni (0.001) and Pb (0.008) in African Egg-plant were below the WHO/FAO and USEPA permissible limits. However, Health risk index of heavy metals in vegetable samples were less than 1 indicating no significant health risk associated with the consumption of vegetables by the consumers.

Key Words: *Proximate, Composition, Health Risk, Heavy Metal, Vegetables.*

1. INTRODUCTION

Leafy vegetables are essential diet components which supply the body with protein, vitamins, fats, minerals, iron, calcium and other nutrients which are usually in short supply amongst the populations of poor tropical nations [4]. Vegetables are the major source of plant protein in order to supplement poor supply of animal proteins and other essential minerals required for normal human health and development [5]. Heavy metal pollution of agricultural soil and vegetables is one of the severe ecological problems in a world scale and also in Nigeria today [6]. Industrial or municipal wastewater is mostly used for the irrigation of crops and vegetables due to its easy accessibility and scarcity of fresh water [7], [8]. Irrigation with wastewater is known to contribute significantly to the heavy metal concentrations in soil and vegetables. Waste water, however, may contain various heavy metals such as Pb, Ni, Cr, Cd, As and Zn, depending on the type of anthropogenic activities associated with it [9]. Heavy metals are very harmful due to their non-degradable nature and their potential to accumulate in different body parts. Heavy metal concentration in the soil solution plays an important role in controlling metal bioavailability to plants [10].

Agriculture which is the backbone of most economy has also been adversely affected by upsurge in the indiscriminate dumping and disposal of wastes into the land and water courses [11]. The continuous pollution of both surface and underground water sources has reduced the quality and quantity of water needed for general agricultural requirements such as meeting crop water requirement during insufficient rainfall. Nonetheless, urban agriculture using waste water for irrigation provides for food, incomes and employment of thousands for people in the cities in Nigeria [11]. Most of the studies show that the use of waste water contaminated with heavy metals for irrigation over long period of time increases the heavy metal contents of soils above the permissible limit. Ultimately increasing the heavy metals contents in soil also increases the uptake of heavy metals by plants depending upon the soil type, plant growth stages and plant species [12]. It is well established that the daily intake of heavy metal contaminated vegetables may pose risk to human health, this is because, heavy metals can accumulate in living organisms and at elevated levels can be toxic [13]. The effects of pH on heavy metal availability to plants has been reported by many researchers and it is acceptable that as pH decreases, the solubility of cations form of metals in the soil solution increases, and therefore, they become more readily available to plants [14], and also explained that pH has a major effect on metal dynamics because it controls adsorption and precipitation which are the main mechanisms of metal retention to soil. Metal solubility in the solution depends on the solubility product of the solid phase (precipitate) containing the metal and that application of sludge increased the CEC value of the soil i.e the ability of the soil to retain metals.

Mpape, Wuse Zone 5 and Wuye areas are agricultural sites located in Abuja metropolis, FCT, Nigeria, along the bank of Mpape River. Vegetables are grown in these areas for domestic and commercial purposes using irrigated water from Mpape River. The river receives copious amount of wastes from residence houses, block industries, mechanic and car wash workshops, sewage sludge, agricultural and municipal dump sites, sited along its course. Urban waste management and garbage disposal practices in this city are very poor. Process water from municipal waste and sewage sludge located near the river contains large amount of heavy metals. The contaminated wastes from Mpape River are used extensively for the irrigation of these vegetables particularly at the agricultural sites during dry seasons [7]. Hence, these pose significant effects on the soil and vegetable crops thereby exposing consumers of these vegetable crops to bioaccumulation of trace metals and anions with time. Therefore, this study is aimed at evaluating some proximate compositions and health risk of heavy metal uptake by these vegetables grown at a waste – water irrigated sites in FCT, Abuja, Nigeria.

2.0 MATERIALS AND METHODS

2.1 Study Area

The study was conducted at three different irrigation sites; Mpape, Wuse Zone 5 and Wuye areas along Mpape River in Abuja Municipal Area Council in the Federal Capital Territory, Nigeria. Mpape River is located at latitude $9^{0} 5'$N and longitude $7^{o} 29'$ E and originates from Mpape Rock in Federal Capital Territory, Abuja, Nigeria (Figure 3.1). The River experiences large influx of wastes from both points and non-point sources, especially during the rainy season. It is used majorly during dry seasons as source of water for irrigation purposes in the area. Inhabitants of this area, however, depend on the river for fishery activities and as well as source of water for domestic purposes. Some industrial activities such as block moulding industries, mechanic workshops, car wash shops take place along the bank of the river. Domestic sewage, agricultural runoffs and domestic wastes are often emptied into the river.

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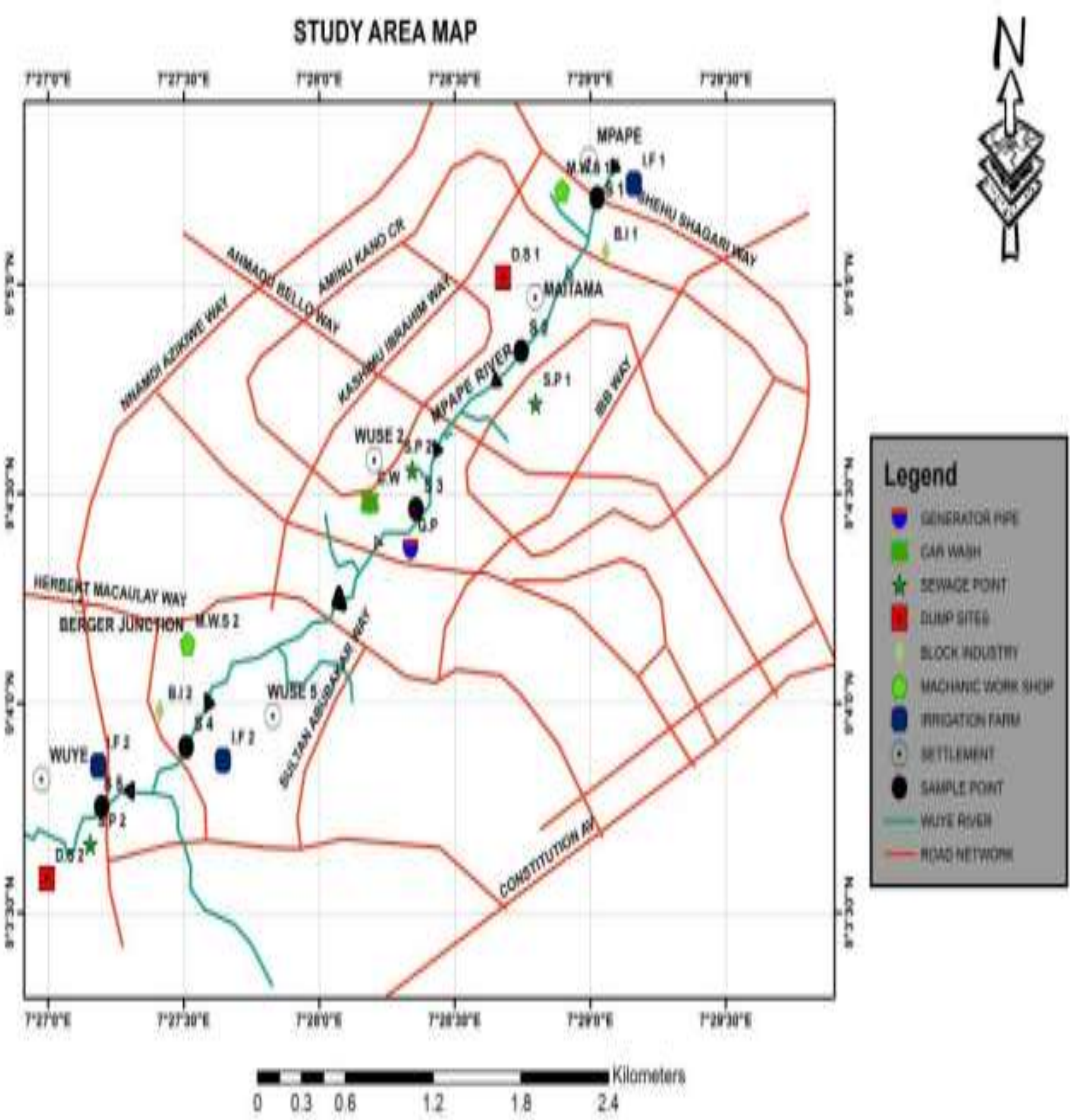

Figure 1: Map of Mpape River showing sampling location

2.2 Sample Collections and Preparations

Fresh samples of two commonly consumed leafy vegetable species (LV) (4 kg) each of Lagos Spinach (*Celosia argentea)* and African Egg- Plant (*Solanum macrocarpon)* were collected randomly from six different locations from three irrigated farm sites to form a composite sample as indicated in Figure 1. This was done by uprooting manually with hands and packaged inside cellophane bags. These vegetables were identified by professor Onovo of Plant and Animal Sciences of Nasarawa State University, Keffi. Vegetable samples were thoroughly washed three times with deionized water to remove all adhered particles in the laboratory, Department of Chemistry, Nasarawa State University Keffi. Vegetables were spread on a tray and air - dried for 3 days in the laboratory. The vegetables were separated into roots, stems and leaves. The leaves were ground to powder using mortar and pestle. The ground samples were pulverised and passed through 125 µm mesh in order to obtain more homogenous samples [15]. The sieved samples were packaged in cellophane bags. Samples were taken to Sheda Science and Technology Complex (SHEDTSCO) in FCT Abuja for Atomic Absorption Spectrophotometer Analysis (AAS) using Buck Scientific 210/211VGP model- USA.

2.3 Sample Digestion and Analysis

Three replicate samples of each vegetable was ashed at 550 ^{0}C for 48 hours; wet digestion of ash samples (2 g) each was carried out using 10 cm^3 of 98 % concentrated nitric acid according to Ladipo *et al. (*2011) with slight modifications. The mixture was heated to complete dissolution in a water bath for 1 hr at temperature of 150 ^{o}C until light coloured solution was obtained. The solution was filtered into 100 cm^3 standard flask using Whatman No.1 and the filtrate was made up with deionised water. The filtrate was stored in a plastic bottle for metal analysis. A total of four heavy metals were investigated for their concentrations in leafy vegetables using AAS. Proximate compositions of vegetables; Crude protein, fat, dry matter, crude fibre and crude ash were analysed using standard methods [16].

2.4 Health Risk Assessment of Heavy Metals in Vegetable Samples

2.4.1 Metal Pollution Index (MPI)

To examine the overall heavy metal concentrations of vegetables, the metal pollution index (MPI) was computed. This index was obtained by calculating the geometrical mean of concentrations of all the metals in the vegetable leaves [17].

$$MPI\ (mg/\ Kg^{-1}) = (Cf_1\ X\ Cf_2\ X \ldots\ldots X\ Cf_n)^{1/n} \qquad (2.1)$$

Where, Cf_{n} = Concentration of metal 'n' in the sample, 'n' = number of metals analysed.

2.4.2 Daily Intake of Metals

The DIM in this study was calculated using the average adult vegetable intake rate of 0.345 kg / person / day based on the formula proposed by [18], [17]. Average body weight of adult consumers (57.9 kg) was obtained through a formal survey conducted in the study areas by interviewing about 30 persons (15 males and 15 females) between the ages of 30 - 45 years and their average body weights taken at each irrigation site.

DIM = Metal Concentration in plants (mg / kg) X Daily Food Intake of vegetables (Kg /person / day) / Average body weight (ABW) (kg). (2.2)

2.4.3 Health Risk Index (HRI)

The health risk index through the consumption of contaminated vegetables from the farm sites was assessed based on the food chain and the oral reference dose (RFD) for each vegetable. Values of HRI depend upon the daily intake of metals (DIM) and oral reference dose (RFD) which was estimated per day exposure of metals to the human body [18]. The health risk index for heavy metals was calculated thus;

$$HRI = DIM / RFD. \qquad (2.3)$$

RFD for Ni = 0.02, Pb = 0.0035, Zn = 0.3, Fe = 0.70 (mg / kg bw / day) [3].

In this work, if the health risk index value is < 1, then the exposed population is considered to be safe but where HIR is equal or greater than 1, the exposed population is considered to be very unsafe [3].

2.4.4 Quality Control

Appropriate safety measures and quality assurance procedures were taken to ensure the reliability of the results. Analytical reagent blanks were prepared with each batch of digestion set and then analysed for the same element in each of the samples. Samples were carefully handled to avoid cross-contamination. Glass wares were properly cleaned and reagents used were of analytical grade. Deionized water was used throughout the studies. Standards were prepared for each metal from their stock solution to calibrate the instruments and also to know the actual concentrations. Reagent blank determinations were used to apply corrections to the instrument readings. For validation (precisions/ Accuracy) of analytical results, replicate analyses of the samples were done for soils and vegetables.

2.4.5 Statistical Analysis

Two- way ANOVA test was carried out in Micro Soft Office Excel 2010 to evaluate the significant difference in the concentration of the four studied metals in the vegetable samples and at the various farm sites at 5% confidence interval. ($P < 0.05$) = is statistically different.

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3.0 RESULTS AND DISCUSSIONS

Results for the Proximate Compositions, Concentrations of Heavy Metals, Metal Pollution Index Values, Daily Intake and Health Risk Assessment of Heavy Metals in Vegetable Leaves are presented in Tables 1 to 5 respectively.

3.1 Proximate Composition (%) in the Leaves of Lagos Spinach and African egg-plant

The proximate compositions of Lagos Spinach leaves are presented in Table 1. Total ash content ranged from 8.89±0.98 to 9. 07±1.12 indicating the highest and lowest values in farms B and C. Crude fibre increased significantly (P=0.05) from 10.12±1.45 to 11.89±1.94, Farm A recorded the highest value while the lowest value was indicated in farm C. Crude protein and dry matter varied from 4.89±0.20 to 5.22±0.23 and 68.22±3.29 to 70.00±3..34 with the highest and lowest values recorded in farms A and B respectively and fat content ranged from 2.87±0.18 to 4.00±0.27 showing farms B and C as recording the lowest and highest values. In African Egg-plant, total ash content varied from 8.46±0.76 to 8.82±0.94, the lowest value was indicated at farm B and the highest at farm C. Crude fibre and protein contents ranged from 10.10±1.34 to 11.30±1.68 and 4.76±0.20 to 5.10±0.21 indicating the highest and lowest values at farms A and B respectively. Fat content varied from 2.56±0.16 to 3.88±0.21 indicating farms A and C as the lowest and highest values while dry matter content varied from 62.34±3.38 to 68.97±3.45 with the highest and lowest values recorded in farms A and C respectively. Higher crude fibre (11.89±1.94 %), protein (5.22±0.23 %) and dry matter (70.00 ±3.34 %) contents; and fat (4.00 ±0.27 %) and ash (9.07 ±1.12 %) contents were recorded in farms A and B for Lagos spinach while higher crude fibre (11.30 ±1.68 %), protein (5.10 ±0.21%) and dry matter (68.97 ±3.45 %); and total ash (8.60 ± 0.87%) and fat (3.88 ±0.21 %) contents were recorded in farms A and C in African Egg-plant respectively.

Table 1: Proximate Compositions (%) of Vegetable Leaves Samples (Lagos Spinach-*Celosia argentea)* and (African Egg-plant-*Solanum macrocarpon)*

	Farms			
Parameters	A	B	C	**Mean± SD**
Lagos Spinach (Celosia argentea)				
Total Ash	9.02±1.16^{b}	9. 07±1.12 ^{b}	8.89±0.98 ^{b}	8.97±1.09 ^{b}
Crude Fibre	11.89±1.94	11.85±1.87	10.12±1.45 ^{b}	11.25±1.75 ^{b}
Crude Protein	5.22±0.23 ^{b}	4.89±0.03^{a}	5.13±0.21 ^{b}	5.08±0.16 ^{b}
Fat	3.00±0.05^{a}	2.87±0.02^{a}	4.00±0.07^{b}	3.29±0.04^{a}
Dry Matter	70.00±3..34 ^{b}	68.22±3.29 ^{b}	68.34±3.21 ^{b}	68.85±3.28 ^{b}
African Egg-plant (Solanum macrocarpon)				
Total Ash	8.60±0.87 ^{b}	8.46±0.76 ^{b}	8.82±0.94 ^{b}	8.65±0.86 ^{b}
Crude Fibre	11.30±1.68 ^{b}	10.10±1.34 ^{b}	11.10±1.11 ^{b}	10.83±1.38 ^{b}
Crude Protein	5.10±0.21 ^{b}	4.76±0.08^{a}	5.02±0.23 ^{b}	4.96±0.17 ^{b}
Fat	2.56±0.04^{a}	2.72±0.08^{a}	3.88±0.06^{a}	3.05±0.06^{a}
Dry Matter	68.97±3.45 ^{b}	65.43±3.42 ^{b}	62.34±3.38 ^{b}	65.58±3.42 ^{b}

Means levels with the same alphabets within the same row are not statistically different (P<0.05).

In general, proximate analysis in both vegetables (Table 1) ranged from (8.65±0.86 to 8.97±1.09) for ash, 10.83±1.38 to 11.25±1.75 % for crude fibre, (4.96 ±0.16 to 5.08 ±0.17 %) for crude protein, (3.05 ±0.04to 3.29±0.18 %) for fat and (65.58±3.28 to 68.85±3.42 %) for dry matter. A similar study conducted for proximate composition in vegetables on irrigated farm land in oil producing area of Port Harcourt [19] reported higher ash content between 9.00 to 26.00 % compared to the lower mean ash contents (8.65±0.86 to 8.97 ±1.09 %) recorded for both vegetables in the present study. The studied vegetables are rich in nutrients and therefore capable of providing the necessary nutrients and adequate diet needed for the healthy body growth. Vegetables provide adequate levels of nutritive potentials and varieties to peoples' dietary. These vegetables yield substantial nutritional contents which have the capacity to enhance healthy living by reducing concentrations of liver cholesterol and also serve as detoxifier [20]. Countries where consumption of diets with high fibre content is high rarely are affected by any of the diseases caused by insufficient nutritive contents such as diabetes, constipations, liver cirrhosis. The nutritional contents of these vegetables were higher compared to the nutritional contents of leafy vegetables in Cote D'ivoire [21], [22]. However, the leaves of Lagos spinach were generally the richest in ash, fibre, fat, protein and dry matter. The content values of proximate composition of both vegetables are in the decreasing order; dry matter>crude fibre>total ash>protein>fat.

3.2 Concentrations of Heavy Metals (mg/kg) in the Leaves of Lagos Spinach-(*Celosia argentea*) and African egg-plant- (Solanum macrocarpon)

Concentrations of heavy metals in the leaves of are presented in Table 2 respectively. Lagos Spinach leaves recorded levels of Fe that ranged from 14.80±0.94 to 15.14 ±0.67 mg/kg. Farm B was relatively higher and the least concentration was in farm A. Zn ranged from 3.03±0.31to 3.92±0.36 mg/kg with the lowest and significantly highest concentrations (p=<0.05) recorded in farms A and B. BDL to 0.06±0.03 mg/kg was recorded for Ni, indicating the highest concentration in farm B, and farm A was below detectable limit. Pb levels ranged from 1.09±0.10 to 1.18±0.13 mg/kg. Farms A and B recorded the lowest and highest concentrations. African egg –plant recorded significant levels of Fe from 15.03±0.97 to 16.52±0.87 mg/kg (P<0.05). Farm B and A indicated highest and lowest concentrations. Zn levels varied from 2.14±0.16 to 3.23±0.45 mg/kg, highest and lowest concentrations were recorded in farms A and B respectively. Levels of Ni ranged from 0.03±0.02 to 0.05±0.03 mg/kg with similar highest concentrations recorded in farms B and C and the lowest in farm A while Pb levels that ranged from 1.08±0.11 to 1.51±0.12 mg/kg recorded lowest concentration in farm A and relatively highest concentration in farm B. However, Cd level (0.01±0.03 mg/kg) in the vegetable leaves were the least and similar in all the farms sites.

Table 2: Concentrations (mg/Kg) of Heavy Metals in the Leaves of Vegetables Samples

	Farms			
Metals	**A**	**B**	**C**	**Mean ± SD**
Lagos Spinach (Celosia argentea)				
Fe	14.80 ± 0.94[b]	15.14 ± 0.67[b]	14.95 ± 0.97[b]	14.96 ± 0.86[b]
Zn	3.03 ± 0.31[b]	3.92 ± 0.36[b]	3.13 ± 0.82[b]	3.36 ± 0.50[b]
Ni	BDL	0.06 ± 0.03[a]	0.03 ± 0.01[a]	0.03 ± 0.01[a]
Pb	1.09 ± 0.10[b]	1.18 ± 0.13[b]	1.07 ± 0.11[b]	1.12 ± 0.11[b]
African egg -plant (Solanum macrocarpon)				
Fe	15.08 ± 0.97[b]	16.52 ± 0.87[b]	15.83 ± 0.79[b]	15.81 ± 0.89[b]
Zn	3.23 ± 0.45[b]	2.14 ± 0.16[b]	3.03 ± 0.47[b]	2.80 ± 0.36[b]
Ni	0.03 ± 0.02[a]	0.05 ± 0.02[a]	0.05 ± 0.03[a]	0.04 ± 0.02[a]
Pb	1.08 ± 0.11[b]	1.51 ± 0.12[b]	1.35 ± 0.09[b]	1.31 ± 0.11[b]

Means levels with the same alphabets within the same row are not statistically different (P<0.05).

BDL = Below Detectable Limit

Iron is present in natural waters in varying quantities and an essential element in human nutrition. It aids in haemoglobin formation in human blood and is needed in transporting oxygen and carbon dioxide in human and its deficiency can lead to anaemia and impairment to enzymes in plants [23]. In excess above 48 mg/day, iron may cause gastrointestinal side effects [24]. The minimum daily requirement of iron is dependent on sex, age, iron bioavailability and the physiology of the individual [25], [26]. An established provisional maximum tolerable daily intake (PMTDI) of 0.8 mg/kg body weight of iron was suggested by [25]. [27], [27] and [28] reported levels of Fe (33.6 to 183.90 mg/kg) and (19.43±0.71 mg/kg) from leafy vegetables on irrigated farmlands in Makera area of Kaduna State and Tanda Dam in Pakistan above mean levels of Fe (14.96±0.86 to 15.81±0.89 mg/kg) in the present study (Table 2). However, similar studies reported lower levels (4.69 to 8.97 mg/kg) and (2.03 to 2.09 mg/kg) for vegetables from farm lands in oil area of Port Harcourt [19]and Mahalgaon in India [29]contrary to the present study. The recorded levels of Fe in the present study were above the 0.3 - 5.0 mg/kg (WHO/FAO) [1] permissible limits. Zinc is an essential nutrient required by the body for growth. It participates in the synthesis and metabolism of lipids, carbohydrates and proteins and high concentrations of zinc may be carcinogenic and capable of causing vascular shock, dyspeptic nausea, and pancreatitis and can also shorten the cell division [30]. Deficiency in zinc can lead to stunted growth and delay in sexual maturity [31]. [32]and [27] reported higher levels of Zn (3.51 to 16.00 mg/kg) and (53.68 to 69.07 mg/kg) from leafy vegetables on irrigated land in Chandigarh, India and Makera area of Kaduna State than the mean levels (2.80±0.36 to 3.36±0.50 mg/kg) recorded in the present study. However, concentrations (0.06 to 0.13 mg/kg) and (0.10±0.03 mg/kg) reported for vegetables from irrigated farms in Lagos State [33] and Tanda Dam in Pakistan [28] were lower than the concentrations recorded in the present study. These values were below the 60 mg/kg [34] and the 20-60 mg/kg (WHO/FAO) [1] permissible limits.

Nickel is essential for growth and reproduction in livestock and man, however, could be carcinogenic in higher amounts in the body [35]. Mean levels of Ni that ranged from 0.03± 0.01 to 0.04±0.02 mg/kg in the present study was contrary to higher levels

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(0.17 to 0.38 mg/kg), (0.13 to 0.29 mg/kg) and (0.42 to 0.67 mg/kg) reported for vegetables cultivated on irrigated farm land in mining areas of Banat in Romania [36], Lagos State [33] and in oil areas of Port Harcourt [19]. The values in the present study were below the 2.3 mg/kg [34] permissible limits. The vegetables do not constitute any health threat from its consumption by humans. About 50 % of lead intake by man comes from drinking water due to its higher solubility in water [37]. Plants absorb lead from deposits on the leaves and other exposed parts to polluted environments, and vegetables such as carrot and cabbage were observed to take up lead and cadmium in contaminated soils from irrigation water in Ghana [38]. Lead posed high health risk to man especially infants, young children and animals by bio-accumulating in the body [39]. There is no established health benefits from lead in human body, however, at a very low concentrations, it is highly poisonous, even young children up to six years and pregnant women face adverse health effects such as damage to nervous system and affects foetus in infant and children resulting in the lowering of intelligence quotient, increase blood pressure, aggravates cancer and reduction in the growth and reproduction in plant cell [40]. Some researchers reported levels of Pb (0.17 to 1.00 mg/kg) and (0.0018 to 0.001 mg/kg) from irrigated land in oil area of Port Harcourt [19] and in Makera area of Kaduna State [27] lower than the mean levels (1.12±0.11 to 1.31±0.11 mg/kg) in the present study. However, these values were above the 0.3- 0.5 mg/kg (WHO/FAO) [1] and the 0.05 - 0.3 mg/kg (EU) [34] permissible limits which is an indication that the vegetables will pose health risk in its consumption. In the two vegetables studied, the highest concentration of Fe, Zn and Pb was recorded in farm B, while Ni concentrations were consistently low in all the farms in both vegetables. Higher metal levels observed at different farm sites in vegetables showed that the probable source of the pollutants was anthropogenic activities arising mainly from agricultural practices and sewage effluence, urban and municipal wastes Heavy metal concentrations from the two vegetables decreased in the order of Fe>Zn>Pb>Ni respectively.

Generally, the maximum mean concentration of Zn was highest in the leaves of Lagos -Spinach; however, Fe and Pb were significantly higher (P=<0.05) in the leaves of African egg-plant. It was observed that Fe and Zn were the most accumulated metal amongst the four metals studied in the leaves of both vegetables while Ni was relatively low. The sequence of mean metal concentrations in the leaves of both vegetable samples was in the decreasing order ; Fe > Zn > Pb > Ni. The difference in the levels of heavy metal concentrations between the two vegetables under study could be due to their morphological differences in terms of heavy metal content, accumulation, foliage deposition and retention efficiency, the root zone and availability of the metals in the soil (Zhuang *et al.*, 2009).

3.3 Metal Pollution Index (MPI)

Metal Pollution Index in the Leaves of Vegetables are presented in Table 3 respectively. Levels of Metal Pollution Index for Lagos Spinach leaves in Fe and Zn ranged from 14.80±0.19 to 15.14±0.21, 3.03±0.04 to 3.92±0.09 indicating the lowest and highest values in farms A and B respectively while Pb ranged from to 1.07±0.06 1.18±0.09 indicating highest and lowest levels at farms B and C. However, in African Egg-plant, Fe and Pb varied from 15.08±0.16 to 16.52±0.67 and 1.09±0.06 to 1.18±0.09 respectively. Farm A and B recorded the lowest and highest levels of metal pollution index. Zn levels ranged from 2.14±0.02 to 3.23±0.07 indicating the highest and lowest levels at farms A and B respectively while Ni level was generally low in both vegetables for all the farm sites.

Table 3: Metal Pollution Index (MPI) mg/Kg in Vegetable Samples

	Farms			
Metals	A	B	C	Mean
Lagos Spinach **(Celosia argentea)**				
Fe	14.80±0.19^{b}	15.14±0.21^{b}	14.95±0.20^{b}	14.96±0.20^{b}
Zn	3.03±0.04^{a}	3.92±0.09^{b}	3.13±0.02^{a}	3.36±0.05^{a}
Ni	BDL^{a}	0.06±0.05^{a}	0.03±0.01^{a}	0.03±0.01^{a}
Pb	1.09±0.06^{b}	1.18±0.09^{b}	1.07±0.06^{b}	1.11±0.08^{b}
Total MPI =10.35				
African Egg-plant (**Solanum macrocarpon)**				
Fe	15.08±0.16^{b}	16.52±0.67^{b}	15.83±0.34^{b}	15.81±0.39^{b}
Zn	3.23±0.07^{b}	2.14±0.02^{a}	3.03±0.03^{a}	2.80±0.04^{a}
Ni	0.03±0.01^{a}	0.05±0.03^{a}	0.05±0.03^{a}	0.04±0.02^{a}
Pb	1.08±0.04^{a}	1.51±0.09^{b}	1.35±0.09^{b}	1.31±0.07^{b}
Total MPI= 12.18				

Means levels with the same alphabets within the same row are not statistically different (P<0.05).

BDL = Below Detectable Limit

The MPI is a reliable and precise method for monitoring metal pollution in vegetables. Among the two vegetables studied, African egg-plant showed the highest total metal pollution index value of 12.18 mg/Kg while Lagos spinach recorded the lowest value of 10.35 mg/Kg (Table 3). [41] reported that the MPI value of 9.74 mg/ Kg for radish and 10.22 mg/ Kg for bottled gourd vegetable leaves were lower than the findings in the present study. The higher MPI value (12.18 mg/Kg) in African Egg-plant suggests that the leaves of the vegetables will pose health risk to the consumers due to its higher heavy metal accumulation.

3.4 Daily Intake of Metals (DIM) kg / person / day in Vegetable Leaves

Daily Intake of Vegetables is presented in Table 4 respectively. Lagos Spinach and African Egg-plant leaves recorded considerable higher values of Fe (0.088 to 0.090), (0.090 to 0.098) and Zn (0.018 to 0.023), (0.013 to 0.018) in all the farm sites respectively, while Ni and Pb were generally low in both vegetables for all the farm sites.

Table 4: Daily Intake of Metals (DIM) (mg/ Kg/ person / day)

	Metals			
Farms	Fe	Zn	Ni	Pb
Lagos Spinach (Celosia argentea)				
A	0.088	0.018	0.000	0.006
B	0.090	0.023	0.001	0.007
C	0.089	0.019	0.002	0.006
Mean	0.089	0.020	0.001	0.006
African egg -plant (Solanum macrocarpon)				
A	0.090	0.019	0.002	0.006
B	0.098	0.013	0.001	0.009
C	0.094	0.018	0.001	0.008
Mean	0.094	0.017	0.001	0.008

In order to appraise the health risk associated with heavy metal contamination of vegetables, the DIM and risk index were calculated. DIM of metals was calculated according to the average vegetable intake rate for adults (0.345 kg / person / day) based on the formula proposed by [17] and [18] and an *in-situ* average mean body weight of 57.90 kg from the farm sites. The result revealed highest intake values of Zn (0.023) and Pb (0.007) in Lagos Spinach in farm B and Fe (0.098) in African Egg-plant in farm A (Table 4). However, lower DIM value was observed for Ni in both vegetables. From the study, the highest mean vegetable intake values for Fe (0.0940) and Pb (0.008) was recorded in African Egg-plant and Zn (0.02) was recorded in Lagos Spinach, while Ni was generally low in both vegetable and in all the farm sites. DIM recorded in this study were far below the 45, 40, 1.4 and 0.24, for Fe, Zn, Ni and Pb WHO/FAO) [2] and USEPA [3] permissible limits, which suggests no potential health risk associated with the consumption of the vegetables.

Generally, in both vegetables, Fe recorded the highest mean DIM value of 0.094 in African Egg-plant probably due to its most abundance in nature. The DIM of metals through consumption of vegetables decreased in the order of Fe>Zn>Pb>Ni in both vegetables. Therefore, it may be concluded that the local population will accumulate higher levels of Fe and Zn.

3.5 Health Risk Assessment (HRI)

Health Risk Index of Heavy Metals in Vegetable Leaves are presented in Table 5 respectively. The health risk index for Fe (0.126 to 0.129), (0.129 to 0.140), Zn (0.060 to 0.063), (0.043 to 0.063) and Ni (0.001 to 0.100), (0.015 to 0.025) were relatively higher in both vegetables while Pb was generally low in all the farm sites.

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Table 5: Health Risk Index (HRI) of Heavy Metals in Vegetable Leaves Samples

	Metals			
Farms	Fe	Zn	Ni	Pb
Lagos Spinach (Celosia argentea)				
A	0.126	0.060	0.001	0.015
B	0.129	0.077	0.050	0.018
C	0.127	0.063	0.100	0.015
Mean	0.127	0.067	0.050	0.016
African egg -plant (Solanum macrocarpon)				
A	0.129	0.063	0.100	0.015
B	0.140	0.043	0.050	0.025
C	0.134	0.060	0.050	0.020
Mean	0.134	0.055	0.067	0.020

The health risk index for heavy metals by consumption of vegetables grown on irrigated farmland was calculated on the bases of the oral reference dose for adults. RFD for Ni = 0.02, Pb = 0.0035, Zn = 0.3, Fe = 0.70 (mg / kg bw / day) (USEPA) [3]. In this study, if the health risk index value is < 1, then the exposed population is considered to be safe and exposure to any significant potential health risks to the population will not be of any great concern from the intake of vegetables [17], [27] but where HIR is equal or greater than 1, the exposed population is considered to be very unsafe and will experience potential health hazards through consumption of vegetables (USEPA) [3]. HRI for metals in all the farms and in both vegetables were < 1 (Table 5). This study indicates that those that consume these vegetables from farmlands might not have been exposed to any significant potential health risks. However, continuous accumulation of these metals over time may have a negative impact on the environment.

HRI values varied in the order of Fe>Zn>NI>Pb in both vegetables. There are other sources of metals exposures, such as consumption of other food stuffs and dust inhalation. There are several possible pathways of exposure to humans but the food chain is the most important [18].

4. CONCLUSION

The build-up of heavy metals due to continuous irrigation with wastewater has led to the contamination of vegetables in the study area. Proximate analysis showed that Lagos Spinach vegetable was richer; however, both vegetables possess useful nutritional contents required for healthy growth such as crude protein, minerals, vitamins and fibre, which will be of enormous advantage to diabetic patients and also reduces high content of cholesterol in the body, aids in digestion of food. The highest mean concentrations of all metals were detected in African Egg-plant leaves except for Zn which was found in the highest concentration in Lagos Spinach leaves. However, Ni was generally low in both vegetables. The mean concentrations of Ni and Zn were below the WHO/FAO and EU permissible limits while Pb and Fe were above the limits. The higher mean value of Metal Pollution Index (MPI) in African Egg-plant indicated that heavy metal contaminations in vegetables present the potential for a significant negative impact on human health. Health Risk Index (HRI) in both vegetables were less than 1, indicating no significant health risk associated with the consumption of the vegetables. Higher mean DIM was recorded for Fe in African Egg-plant while Ni was generally low in both vegetables; however, they were below the WHO/FAO and USEPA, permissible limits. Higher metal levels observed at different farm sites in vegetables showed that the probable source of the pollutants was anthropogenic activities arising mainly from agricultural practices and sewage effluence, urban and municipal wastes, Therefore, regular monitoring of these toxic heavy metals from industrial effluents into Mpape River is required in order to minimise pollution and contamination by vegetables planted using the river as source of irrigation to prevent their excessive build-up in the food chain.

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