Journal of Agriculture and Ecology Research International
1(1): 18-29, 2014; Article no. JAERI.2014.002

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Trace Metal Contamination of Selected Vegetables Grown Around Owerri Municipality, Nigeria

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Authors' contributions

This work was carried out in collaboration between all authors. Author CON designed the study, performed the statistical analysis. Author ENE performed the experiment and wrote the first draft of the manuscript. Author CEU managed the literature searches. All authors read and approved the final manuscript.

Original Research Article

Received 1st May 2014
Accepted 21st May 2014
Published 30th June 2014

ABSTRACT

Trace metal contamination of vegetables grown around urban city of Owerri southeastern Nigeria was assessed. Vegetables: Fluted pumpkin – *Telfairia occidentalis,* Waterleaf – *Talinum triangulare,* Green – *Amaranthus hybridus)* were sampled along major locations of the metropolis based on the traffic intensity to achieve very high, high and low urban activities. Shoot of washed and unwashed samples were sub sampled and analyzed for Pb, Cd, Cr and Cu. Results showed that washing significantly reduced trace metal contamination of vegetables. Trace metal pollution index (TPI) was maximum for Douglas (1.72), followed by Aladinma (0.66), Orji (0.61) and Umunjam (0.57). The percentage reductions in trace metal concentrations due to washing were found highest for Pb, Cd, Cr in *T. triangulare*, *A. hybridus* and *A. hybridus*, respectively in Umunjam, Aladinma and Orji. There is need for continuous monitoring of trace metal contamination of vegetables grown in urban and suburban cities to reduce risk associated with trace metal contamination.

Keywords: Trace metal; metal-uptake; vegetables; urban activity.

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1. INTRODUCTION

In Nigeria and other parts of the world, the act of growing vegetable crops around open urban cities has become a common practice. This recent development could increase availability of the commodity and alleviate hunger and malnutrition. Trace metal contamination of agricultural soils and Vegetables grown around busy urban centers have been widely reported in the literature [1,2,3]. Public health implication of ingestion of trace metal contaminated crops may have scaled up research in this field. Food chain transfer of trace metal has been considered as predominant pathway for human and animal exposure in high risk areas [4]. According to numerous studies, the pollution sources of trace metals in environment are mainly derived from anthropogenic sources. In urban soils and urban road dusts, the anthropogenic sources of trace metals include traffic emission (vehicle exhaust particles, tire wear particles, weathered street surface particles, brake lining wear particles), industrial emission (power plants, coal combustion, metallurgical industry, auto repair shop, chemical plant, etc.), domestic emission, weathering of building and pavement surface, atmospheric deposited and so on [5,6,7]. However, the anthropogenic sources of trace metals in agricultural soils include mining, smelting, waste disposal, urban effluent, vehicle exhausts, sewage sludge, pesticides, fertilizers application and so on [8].

The uptake and bioaccumulation of trace metals in vegetables are influenced by a number of factors such as climate, atmospheric depositions, the concentrations of trace metals in soil, the nature of soil on which the vegetables are grown and the degree of maturity of the plants at the time of harvest, plant type and genetic composition [9,10] Homestead gardens near highways are also exposed to atmospheric pollution in the form of metal containing aerosols. These aerosols can be deposited on soil and are absorbed by vegetables, or alternatively deposited on leaves and fruits and then absorbed. Voutsa [11] have reported high accumulation of Pb, Cr and Cd in leafy vegetables due to atmospheric depositions. Field studies have found positive relationships between atmospheric metal deposition and elevated concentrations of trace metals in plants and top soil [12,13]. Onianwa et al. [14] reported levels of Cu, Pb, Mn, Ni and Cd in some selected vegetables irrigated with water from River Benue within Makurdi Metropolis, Benue State Nigeria.

The partitioning of trace metals is well known, with accumulation of greater concentrations in the edible portions of leafy or root crops than the storage organs or fruits [15,16]. Air-borne trace metals can significantly influence total metal concentration of vegetables especially when not thoroughly washed. Nwoko and Mgbeahuruike [17] observed significant levels of Pb, Zn, Cu on ready-to-use herbal remedies in south eastern Nigeria. Owerri, is assuming a cosmopolitan city with the current developmental strides of the democratic government which has led to increased urban activity. Therefore, it becomes very imperative to assess the contribution of urban activities on the concentration of trace metal uptake on crops grown in the city. This present study was conducted to assess the trace metal concentration of some selected vegetable crops grown around streets of Owerri capital and its environs.

2. MATERIALS AND METHODS

The study was carried out from June 2011 to March 2012 in the capital city of Owerri, Imo state Nigeria located (Fig. 1). Owerri city lies within the Nigeria humid rain forest zone, which ecologically is more prominent for tuber than cereal production. It has minimum and maximum annual ambient temperatures of 20ºC and 32ºC [18]. Rainfall distribution is bimodal with peaks around the months of June and September. The dry season extends from

November to March with a characteristic cold, dry, dust laden interval (harmattan) during the months of January through February. The air temperatures at this harmattan are relatively higher than other times.

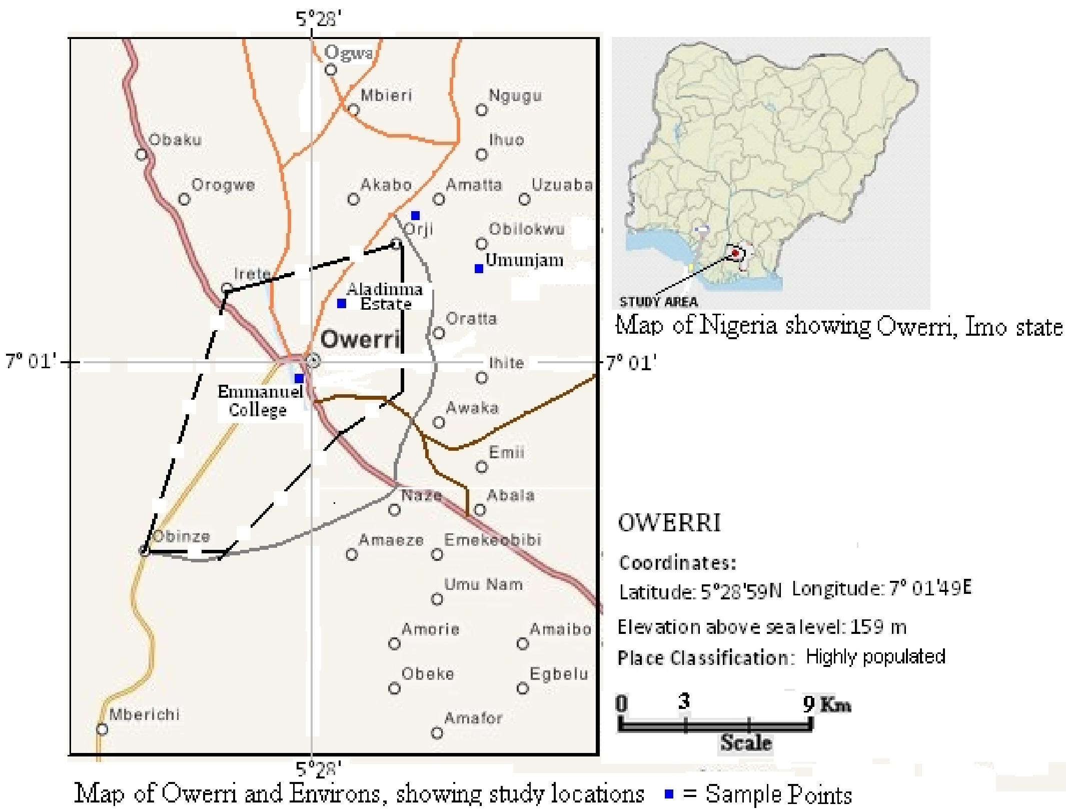

Fig. 1. Map of Owerri urban settlement

Owerri is one of the cosmopolitan cities in Nigeria. There are many small scale industries dispersed in the industrial layout, auto mechanic villages located at Nekede, Orji and many Diesel Locomotive Works. A number of brick industries are also located at the periphery of the city. Trace traffic on narrow roads leading to frequent traffic congestion is a common occurrence within the city.

The city was divided into 4 major grids of 1.5 km^2 and then 32 sampling locations were selected where vegetables grown in nearby open urban areas were collected. These sampling locations were categorized into 4 groups based on the magnitude of urban activity. Viz: very high urban activity, high urban activity and low urban activity and suburban area (regarded as background trace metal contamination) representing Douglas area, Aladinma area, Orji area and Umunjam village, respectively.

2.1 Sample Collection

Common vegetables grown along these sampling grids were collected. Four different sub-sampling points were located at each grid and vegetables such as Fluted pumpkin – *Telfairia* *occidentalis,* Waterleaf – *Talinum triangulare,* Green – *Amaranthus hybridus)* were collected. Similar vegetables were also randomly collected from Umunjam village. Soil samples (0-15cm) were also collected at each sample grid. The shoot portion of the vegetables collected from each sampling point was divided into two portions. One portion was thoroughly washed using tap water and then distilled water. The other portion was left unwashed. Both were separately chopped into pieces and oven dried at 80ºC till a constant weight was achieved. The dried washed and unwashed vegetables were blended separately using a commercial blender (TSK-Westpoint, France), and were ready for analysis. The soil samples were air dried and sieved to pass through 2 mm sieve size and was ready for analysis.

2.2 Analytical Procedure for Trace Metal Determination

Two gram soil sample was weighed into 50-ml beaker, followed by the addition of 10 ml mixture of analytical grade acids HNO_3: HCl in the ratio 5:1. Digestion was performed at a temperature of about 80-90ºC for 1.5 h with electric hot plate (HP 220, UTEC products Inc., Albany N. Y., USA). After cooling, the solution was made up to a final volume (30 ml) with distilled water in a volumetric flask. Similar procedure was carried on 1g blended vegetable samples. The metal (Pb, Cd, Cr and Cu) concentrations were determined on both soil and vegetable samples using Atomic Absorption Spectrophotometer (AAS) (model: SOLAR UNICAM 969) (Table 1). Analysis of each sample was carried out three times to obtain representative results and the data reported in mg/kg (on a dry matter basis)

2.3 Transfer Coefficient and Trace Metal Pollution Index (TPI)

Transfer coefficients (TC_{metal}) were calculated on a dry weight basis by dividing the metal concentration in the plant (mg kg^{-1}) by the metal concentration in the soil (mg kg^{-1}). Pollution index was determined using the equation by [19].

$$TPI = (TC_1 \times TC_2 \times TC_3 \ldots\ldots\ldots\ldots TC_n)^{1/n}$$

where *TC* is the concentration of *n* trace metals in vegetable samples.

Table 1. Wavelength and detection limits of each trace metal, measured by atomic absorption spectrophotometer

Elements	Wavelength (nm)	Detection limits (mg/l)
Pb	213.3	0.0010
Cu	324.8	0.0010
Cr	357.9	0.0010
Cd	288.8	0.0010

2.4 Statistical Analysis

Statistical differences were performed using ANOVA and significant means were grouped by Tukey's multiple range tests at 5% significant level using Minitab statistical package version 16.

3. RESULTS

There were significant ($p<0.05$) trace metal contamination of all the vegetables collected from Douglas, Orji, Aladinma and Umunjam (Tables 2-5). *T. triangulare* had the highest Pb tissue content of 1.997±0.006 mg/kg, followed by *T. occidentalis*: 1.057±0.006 mg/kg and *A. hybridus*: 0.613±0.006mg/kg in Douglas (Table 2). Washing significantly reduced trace metal concentration of all the vegetables sampled. The highest reduction at Douglas road was 51.7% (Cr) and was observed in *Telfairia occidentalis,* followed by *A. hybridus* 43% (Pb).

The highest reduction of 97.2% in Cd was observed in *A. hybridus* followed by Cr (Table 3). Chromium concentration of both wash and unwash vegetable tissues was the least compared to other metal species.

In Orji sampling location washing did not reduce Cd and Cr concentration of shoot of *T. occidentalis* and *A. hybridus*. However, significant reduction in Cr was observed in *T. triangulare* and *T. occidentalis* respectively (Table 4).

Soil trace metal contamination ranged from Pb: 0.5±0.02-3.3±0.12 mg/kg, Cu: 6.6±1.2 - 15.6±2.43mg/kg, Cr: <0.01±0.00-1.7±0.23mg/kg, Cd:<0.01±0.01-2.6±1.1mg/kg (Table 6). pH ranged from 5.3±2.0-6.1±2.1 soil cation exchange capacity ranged from 87±12.3-122±13.2mmolckg^{-1}.

The metal transfer co-efficient of different vegetables collected from the sampling location is shown in (Table 7). The transfer co-efficient of Pb, Cu, Cr and Cd in each of the vegetables collected from Douglas were below 1.0 (<1) with *Talinum triangulare* having the highest co-efficient in each of the trace metals Pb (0.38), Cu (0.54), Cr (0.45) and Cd (0.44). Cr in fluted pumpkin (0.05) showed the lowest co-efficient value. Whereas in Aladinma Pb and Cu showed transfer values >1 in *Telfairia occidentalis* and *Talinum triangulare* while Cr and Cd showed transfer values <1 in all the vegetables, except in *Talinum triangulare* where Cr showed value >1 (1.01). Cu in *Telfairia occidentalis* (1.16) showed the highest value while *Amaranthus hybridus* showed the lowest co-efficient value.

Lead (Pb) showed a transfer coefficient value >1 in all the vegetables, while Cu, Cr and Cd gave transfer values <1.0 Pb (1.22) in *Telfairia occidentalis* contained the highest coefficient values whereas Cd in *Telfairia occidentalis* and *Amaranthus hybridus* showed the lowest value of 0.01. In Umunjam, Cu showed values <1 in *Telfairia occidentalis* and *Talinum triangulare*; *Amaranthus hybridus* showed value <1 in Pb. The highest coefficient value of 0.81 was observed in *A. hybridus* in Pb, whereas Pb (0.02) *Talinum triangulare* showed the lowest transfer value.

The trace metal pollution index (TPI) is shown in (Table 8), Douglas road showed the highest value (1.72) followed by Aladinma (0.66), Orji (0.61) and Umunjam (0.57).

Table 2. Shoot trace metal concentration (mg/kg) collected from Douglas road

Vegetable sample **	Pretreatment method	Pb (mg/kg)	Cu (mg/kg)	Cr (mg/kg)	Cd (mg/kg)
Telfairia occidentalis	Wash	1.057±0.006[b]	14.867±0.058[b]	0.090±0.001[c]	0.713±0.006[b]
	Unwash	1.487±0.006[c]	18.367±0.058[c]	0.283±0.167[c]	0.787±0.006[b]
% reduction		16.9	10.5	51.7	4.93
Talinum triangulare	Wash	1.997±0.006[a]	18.190±0.010[a]	0.737±0.318[b]	1.123±0.006[a]
	Unwash	2.427±0.006[a]	19.348±0.006[b]	0.763±0.006[a]	1.473±0.006[a]
% reduction		9.71	3.088	1.733	13.4
Amaranthus hybridus	Wash	0.613±0.006[c]	13.590±0.061[c]	0.593±0.015[b]	0.333±0.006[c]
	Unwash	1.540±0.010[b]	19.763±0.058[a]	1.077±0.006[a]	0.543±0.006[c]
% reduction		43	18.5	28.9	23.9
Safe limit*		3.0	40.0	-	0.3

** FAO/WHO Standard (Codex Alimentarius commission, 2001). ** number of sample, n=4,*
Means were separated based on the pretreatment method. Specific values of pretreatment method within columns bearing the same letters are not significantly different at 5%

Table 3. Shoot trace metal concentration (mg/kg) collected from Aladinma

Vegetable sample **	Pretreatment method	Pb (mg/kg)	Cu (mg/kg)	Cr (mg/kg)	Cd (mg/kg)
Telfairia occidentalis	Wash	0.967±0.006[a]	14.530±0.052[a]	0.010±0.000[a]	0.553±0.006[a]
	Unwash	1.137±0.006[c]	16.130±0.010[a]	0.010±0.000[a]	0.683±0.006[b]
% reduction		8.1	5.22	-	10.5
Talinum triangulare	Wash	0.963±0.006[a]	12.967±0.058[b]	0.004±0.005[b]	0.413±0.006[b]
	Unwash	1.197±0.006[b]	15.523±0.006[b]	0.010±0.000[b]	0.487±0.006[c]
% reduction		10.8	8.87	42.8	8.22
Amaranthus hybridus	Wash	0.897±0.006[b]	9.367±0.058[c]	0.001±0.000[b]	0.010±0.000[c]
	Unwash	1.597±0.006[a]	13.830±0.010[c]	0.010±0.000[c]	0.723±0.006[a]
% reduction		28.06	19.23	81.8	97.2
Safe limit*		3.0	40	-	0.3

** FAO/WHO Standard (Codex Alimentarius commission, 2001). ** number of sample, n=4,*
Means were separated based on the pretreatment method. Specific values of pretreatment method within columns bearing the same letters are not significantly different at 5%

Table 4. Shoot trace metal concentration (mg/kg) collected from Orji

Vegetable sample **	Pretreatment method	Pb (mg/kg)	Cu (mg/kg)	Cr (mg/kg)	Cd (mg/kg)
Telfairia occidentalis	Wash	0.953±0.006[a]	12.067±0.006[a]	0.513±0.006[b]	0.010±0.000[b]
	Unwash	1.050±0.087[b]	15.133±0.006[a]	0.967±0.006[b]	0.010±0.000[c]
% reduction		4.85	11.2	30.6	-
Talinum triangulare	Wash	0.917±0.012[b]	8.31±0.012[b]	0.613±0.006[a]	0.297±0.006[a]
	Unwash	1.077±0.006[b]	14.443±0.006[b]	1.163±0.006[a]	0.463±0.006[b]
%reduction		8.02	26.95	30.96	21.84
Amaranthus hybridus	Wash	0.843±0.006[c]	6.667±0.058[c]	0.010±0.000[c]	0.010±0.000[b]
	Unwash	1.547±0.006[a]	10.877±0.006[c]	0.010±0.000[c]	0.577±0.006[a]
% reduction		29.4	23.9	-	96.5
Safe limit*		3.0	40.0	-	0.3

** FAO/WHO Standard (Codex Alimentarius commission, 2001). ** number of sample, n=4,*
Means were separated based on the pretreatment method. Specific values of pretreatment method within columns bearing the same letters are not significantly different at 5%

Table 5. Shoot trace metal concentration (mg/kg) collected from Umunjam

Vegetable sample **	Pretreatment method	Pb (mg/kg)	Cu (mg/kg)	Cr (mg/kg)	Cd (mg/kg)
Telfairia occidentalis	Wash	0.930±0.010[a]	10.520±0.010[a]	0.373±0.006[a]	0.787±0.006[a]
	Unwash	1.007±0.006[b]	13.537±0.006[a]	0.637±0.006[a]	1.137±0.006[a]
% reduction		3.97	12.54	26.1	18.2
Talinum triangulare	Wash	0.010±0.000[c]	7.923±0.006[b]	0.227±0.006[b]	0.517±0.006[b]
	Unwash	1.057±0.006[a]	13.457±0.006[b]	0.423±0.006[b]	0.747±0.006[b]
% reduction		98.1	25.8	30.1	18.2
Amaranthus hybridus	Wash	0.303±0.006[b]	1.957±0.023[b]	0.010±0.000[c]	0.010±0.000[c]
	unwash	0.813±0.000[b]	2.757±0.006[c]	0.010±0.000[c]	0.010±0.000[c]
% reduction		45.6	16.9	-	-
Safe limit*		3.0	40.0	-	0.3

** FAO/WHO Standard (Codex Alimentarius commission, 2001). ** number of sample, n=4,*
Means were separated based on the pretreatment method. Specific values of pretreatment method within columns bearing the same letters are not significantly different at 5%

Table 6. Trace metal concentrations (mg/kg) and chemical properties of soil samples collected from Douglas, Aladinma, Orji and Umunjam

Sample areas	Pb (mg/kg)	Cu (mg/kg)	Cr (mg/kg)	Cd (mg/kg)	pH	CEC (mmolckg^{-1})	EC (µS/cm)
Douglas	3.3±0.12	15.6±2.43	1.7±0.23	2.6±1.1	6.1±2.1	100±22.5	1023±14
Aladinma	0.9±0.01	12.5±2.02	0.4±0.03	0.8±0.01	5.3±2.0	98±13.3	1103±34
Orji	0.8± 0.03	13.4± 2.12	0.9±0.14	0.7±0.1	6.2±1.8	87±12.3	987±23
Umunjam	0.5± 0.02	6.6±1.2	<0.01±0.00	<0.01±0.01	5.3±1.4	122±13.2	1043±34

Table 7. Transfer co-efficient of vegetables (washed) collected from Douglas, Aladinma, Orji and Umunjam

Vegetables	Trace metals	Douglas	Aladinma	Orji	Umunjam
Telfairia occidentalis	Pb	0.20	1.06	1.22	0.07
	Cu	0.44	1.16	0.90	0.60
	Cr	0.05	0.03	0.60	-
	Cd	0.28	0.72	0.01	-
Talinum triangulare	Pb	0.38	1.06	1.18	0.02
	Cu	0.54	1.03	0.62	0.21
	Cr	0.45	1.01	0.72	-
	Cd	0.44	0.54	0.43	-
Amaranthus hybridus	Pb	0.12	0.99	1.08	0.81
	Cu	0.40	0.75	0.50	0.30
	Cr	0.35	0.00	0.01	-
	Cd	0.13	0.01	0.01	-

Table 8. Trace metal pollution index (TPI) of the studied areas

Study areas	Trace metals				
	Pb	Cu	Cr	Cd	TPI
Douglas	1.54	9.15	0.69	0.89	1.72
Aladinma	1.21	7.67	0.03	0.70	0.66
Orji	1.15	6.98	0.33	0.23	0.61
Umunjam	0.32	4.73	0.23	0.30	0.57

4. DISCUSSION

Urban activities and vehicular movement in developing countries introduce trace metals in nearby arable soils resulting in contamination of edible plant species. Consumption of contaminated vegetables may pose risk to human health. In this experiment, Trace metals determined in different vegetables showed that concentrations of Pb, Cu, Cr have not exceeded the safe limits of both FAO/WHO standards. However, Cd exceedence of safe limit was observed in washed vegetable tissues of *T. occidentalis*, *T. triangulare*, *A. hybridus* collected from Douglas road, also in Aladinma of *T. occidentalis and T. triangulare.* In Umunjam Cd exceedence occurred in *T. occidentalis* and *T. triangulare.*

The variations in the concentrations of the trace metals in vegetables may be attributed to the trace metal concentrations of soil and air in those locations and also to the adsorption of trace metals from aerial depositions during physiological growth of the plant species. The concentration of Pb (mg/kg dry weight) was found maximum in *T. triangulare* (2.42 –unwash, 1.997-washed) followed by *T. occidentalis* (1.487-unwash, 1.057-washed) in Douglas, an area with high population density and trace traffic load. Soil Pb contamination may have contributed to high Pb tissue concentration in this location apart from aerial deposition. Trace metal pollution index (TPI) was also found maximum for Douglas (TPI: 1.72) followed by Aladinma (TPI: 0.66), Orji (TPI :0.61) and Umunjam (TPI: 0.57) this suggest that among the four locations, Douglas received the highest trace metal contamination through aerial deposition and urban activities.

Reduction in trace metal concentrations in vegetables due to washing further suggests that atmospheric depositions on vegetables during physiological growth are a major source of trace metal contamination in urban areas. The high trace metal uptake expressed in some vegetables may be attributed to differences in metal solubility, soil factor and plant species [20,2,21].

The percent reductions in trace metal concentrations due to washing were found highest for Pb, Cd, Cr, in *T. triangulare*, *A. hybridus*, and *A. hybridus*, respectively in Umunjam, Aladinma, and Orji. Unwashed samples of *T. triangulare* however, showed maximum concentrations of Pb, Cu and Cd. The order of percent reductions in trace metal concentrations due to washing was Cr > Pb > Cd > Cu in Douglas and Aladinma was Cd > Cr > Pb > Cu and Orji: Cd >Cr>Pb>Cu while in Umunjam was Pb>Cr>Cd>Cu which suggests that all the metals have varied tendencies for aerial deposition in those locations [19]. Singh and Kumar (2006) also found that Cu concentrations reduced minimally upon washing of *B. vulgaris* and *A. esculentus* in Delhi and *B. vulgaris* and *A. esculentus* showed highest adsorption efficiency for Cu, however, *B. oleracea* showed highest adsorption efficiency for Zn.

The tendency of the vegetables to absorb trace metals from the soil was found to be low in some locations as evidenced from the low value of transfer coefficient. Soil physicochemical properties are mostly responsible for metal plant uptake. Soil pH level influences solubility of trace metal species and thus affect uptake by plant species. Susceptibility of different plant species to trace metal uptake has played significant role to prevent trace metal contamination of some plant species.

Trace metals are harmful because they are non-biodegradable and cause adverse effects in human beings at certain level so analysis of trace metals in leafy vegetables is important because of its toxicity, e.g. Lead affects the CNS, causes abdominal pain, head ache, irritability, joint pain, fatigue and anemia; cadmium causes kidney damage; copper affect the liver and causes kidney damage and gastrointestinal distress, bone diseases, renal failure, dermatitis, pulmonary cancer, etc. Diseases like chrome-hold ulcer, dermatitis, nasal perforation and gastrointestinal disorders etc have been reported [22].

The trace metals such as Pb, Cu, Cr, and Cd are among the most common environmental contaminants resulting from anthropogenic activities and the weathering of natural mineral deposits. These metals occur in a variety of chemical forms that can vary widely in solubility, mobility, toxicity and bio-availability which may result in their up-take and accumulation by vegetables, and consumption of contaminated vegetables may pose risk to human health. Trace metal levels in vegetables studied are within safe limits FAO/WHO [23] for Pb, Cu, Cr, and exceeded for Cd. While trace metal concentrations of the vegetables varied, the concentration of Cu was highest in *T. triangulare* in all the study areas.

Urban areas of developing countries often receive atmospheric depositions in forms of dust particles and water droplets [24] resulting in trace metal contamination of vegetables. Washing therefore reduces adhered particles on the leaf surface since a large amount of the trace metals is bound to particles and water soluble aerosols. These findings collaborate with the work of [25], who investigated vegetables in Lagos, Nigeria for Cu, Pb, and Zn content. The tendency of the vegetables to absorb trace metals from the soil was found to be low as the vegetables studied showed low transfer value.

5. CONCLUSION

There were significant variations in the trace metal concentration in the vegetables analyzed. Aerial trace metal deposition formed part of shoot vegetable contamination in addition to root uptake. Vegetable washing significantly reduced trace metal pollution load of individual vegetable species in all the sampling locations. From the TPI data, it is clear that Douglas road is maximally contaminated with trace metal followed by Aladinma, Orji and Umunjam. There is need for continuous monitoring of trace metal contamination of vegetables grown in urban and suburban cities to reduce public health risk.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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