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Heavy Metals Contamination and Potential Human Health Risk via Consumption of Vegetables from Selected Communities in ONELGA, Rivers State, Nigeria

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Authors' contributions

This work was carried out in collaboration between both authors. Both authors read and approved the final manuscript.

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ABSTRACT

Background: Anthropogenic activities such as excessive oil exploration, automobile emissions with agricultural activities, etc tend to elevate the concentrations of heavy metals in the soil. These metals are accumulated by plant roots, thereby resulting to heavy metal contamination of such plants.
Objectives: This study evaluated the concentration of heavy metals namely: Lead (Pb), Cadmium (Cd), Nickel (Ni), Arsenic (As), Iron (Fe), and Copper (Cu) in edible vegetables from selected communities in Ogba/Egbema/Ndoni Local Government Area (ONELGA), Rivers State, Nigeria, and the concentrations of these metals were used to assess the human health risk posed to the consumers of the edible vegetables.
Materials and Methods: Sixteen different vegetable samples comprising *Vernonia amygdalina, Talinum triangulare*, *Abelmoschus esculentus* and *Telfairia occidentalis* were digested and analyzed for heavy metals using Flame Atomic Absorption Spectrophotometer (F-AAS). Results obtained from this study were used to estimate the human health risk of these heavy metals.
Results: The results showed that the concentrations of Pb, Cd, Ni, As, Fe, and Cu ranged from 0.168-4.908; 0.364-2.977; 2.780-10.241; 0.157-2.633; 61.589-101.520 and 12.029-46.540 mg/kg, respectively. The concentrations of Pb, Cd, Ni and As in some of the analyzed vegetable samples

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exceeded the permissible limit as recommended by WHO/FAO, EC/CODEX and NAFDAC respectively. The concentration of Fe and Cu were below the permissible limit as recommended by WHO/FAO. The Estimated Daily Intake (EDI) of Pb and Cd exceeded the permissible tolerable daily intake of metals (TDI) but fall within the upper tolerable daily intake (UTDI) recommended by Institute of medicine, FDA, also Ni, Fe, and Cu fall within the recommended TDI and the UTDI. The EDI values of As exceeded the recommended TDI and the UTDI. The Target Hazard Quotient (THQ) and Hazard Index (HI) values of Pb, Cd, Cu and Ni were greater than 1. The Life Cancer Risk (LCR) of Pb were within the range of permissible predicted lifetime risks for carcinogens as recommended by US EPA.

Conclusion: The result from the present study indicate that the exposed population may be at risk of Pb, Cd, Ni and Cu toxicity.

Keywords: Heavy metals; anthropogenic; food safety; risk assessment.

1. INTRODUCTION

Heavy metals are hazardous contaminants in food and the environment and they are non-biodegradable having long biological half-lives [1]. The implications associated with heavy metals contamination are of great concern, particularly in agricultural production systems [2,3] due to their increasing trends in human foods and environment. Food safety has been a general concern in recent years [4,5].

Vegetables are an important part of the human diet because they contain carbohydrates, proteins, vitamins, minerals as well as trace elements. These metals can pose a significant health risk to humans, particularly in elevated concentrations above the very low body requirements [6]. So, the metals must be controlled in food sources in order to assure public health safety [7].

Excessive amount of heavy metals in food cause a number of diseases, especially cardiovascular, renal, neurological, and bone diseases [8].These metals could reach food chain through various biochemical processes and ultimately biomagnified in various trophic levels and eventually threaten the health of humans.

Heavy metals enter into plants mainly via roots from the soil and travel along the food chain [9].Once entered in the bodies of living organisms, heavy metals can pose serious threats due to their non-biodegradable nature, long biological half-lives and their potential to accumulate in different body parts, e.g., fatty tissues [10]. Moreover, most of the heavy metals are extremely toxic because of their solubility in water. Even low concentrations of heavy metals have damaging effects on human and animal populations [11,12] by causing cardiovascular, kidney, nervous, mental impairment and bone diseases [13].

The contamination of soil and vegetables by heavy metals is also a global environmental issue. They are ubiquitous in the environment through various pathways, due to natural and anthropogenic activities such as addition of manures, sewage sludge, fertilizers and pesticides to soils, oil exploration, mining, railings, industrial wastes, agricultural runoff, occupational exposure, paints,treated timber and aerosols [14].

Excessive accumulation of heavy metals in agricultural soils through the use of agrochemicals and by other sources may not only result in soil contamination but also lead to elevated heavy metal uptake by vegetables and thus affect food quality and safety [15].

However, this study was designed to assess the level of heavy metals Pb, Cd , Ni, As, Fe, and Cu in four most grown and consumed vegetable species: Bitter leaf (*Vernonia amygdalina*), Water leaf (*Talinum triangulare*) Okra leaf (*Abelmoschus esculentus*), and Fluted pumpkin (*Telfairia occidentalis*) in selected communities in ONELGA and also to assess the potential health risk associated with their daily intake.

2. MATERIALS AND METHODS

2.1 Study Area

The present study was carried out in Ogba/Egbema/Ndoni Local Government Area (ONELGA) in Rivers State, at East Longitude 70˚31' – 120˚45', North latitude 60˚71' – 100˚40'. Ogba/Egbema/Ndoni Local Government Area (ONELGA) is a Local Government Area in Rivers State located in the South-South region of

Nigeria as shown in Fig. 1. The population of ONELGA is about 200,000 people [16] with the capital located at Omoku. It is a major hub for oil and gas exploration by major international oil companies (IOCs) in the Niger Delta region.

2.2 Sample Collection

Fresh samples each of the four selected vegetables namely, *V. amygdalina, T. triangulare, A. esculentus* and *T. occidentalis*were collected randomly from different farms from the selected communities in ONELGA, Rivers State. The samples were properly tagged according to communities in polythene bags and taken to the Herbarium of Plant Science and Biotechnology Department, University of Port Harcourt for identification, and subsequently taken to the laboratory for heavy metal analyses.

2.3 Sample Preparation

Leafy vegetable samples were washed with tap water thoroughly to remove dust particles, soil, unicellular algae etc. The edible parts of the samples were further washed with distilled water and finally with deionized water. The washed vegetables were dried with blotting paper followed by filter paper at room temperature to remove surface water. The vegetables were immediately kept in desiccators to avoid further evaporation of moisture from the materials. After that the vegetables were chopped into small pieces they were oven dried at 55± 1 °C. Then the vegetables were crushed into fine powder using a porcelain mortar and pestle. The resulting powder was kept in air tight polythene packet at room temperature before being taken to the laboratory for digestion and metals analyses.

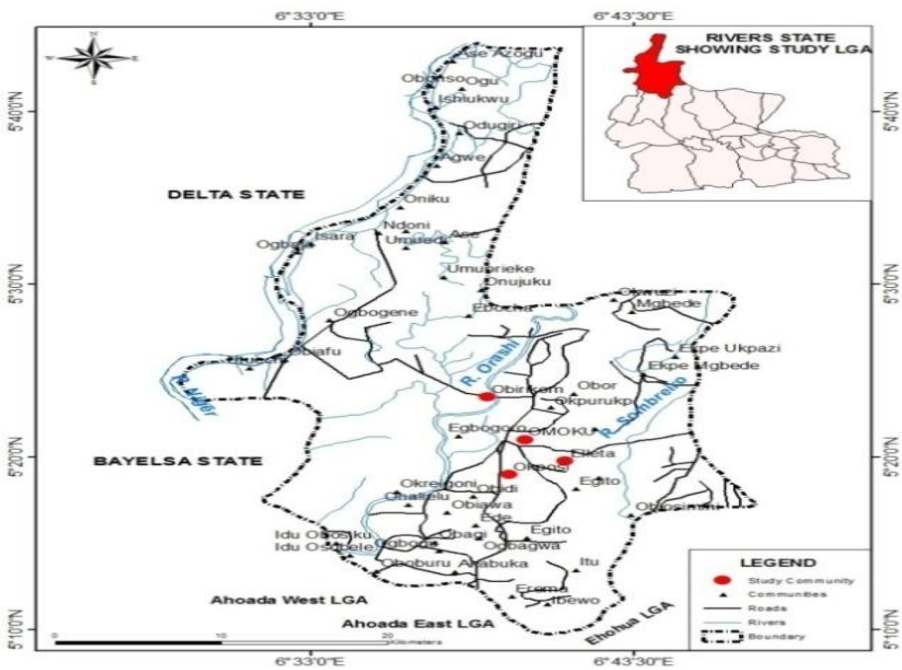

Fig. 1. Map showing research area and sampling points in ONELGA, Rivers State, Nigeria

Table 1. Vegetables used for the study

S/n	Common name	Botanical name	Local name	Family name	Parts used in the study
1	Bitter leaf	*Vernoniaamygdalina*	Olugbu*	Compositae	Leaves only
2	Water leaf	*Talinumtriangulare*	Gbure**	Portulacaeae	Leaves only
3	Okra leaf	*Abemoschusesculentus*	Ila**	Malvaceae	Leaves only
4	Fluted pumpkin	*Telfariaoccidentalis*	Ugu*	Cucurbitaceae	Leaves only

**: Igbo language; **: Yoruba language*

2.4 Digestion and Metal Analysis

5 g of each samples was measured into a clean dried beaker (100 mL), 2 mL of acidic mixture of H_2SO_4, HNO_3, and $HClO_4$in ratio 40:40:20 [17], was then added to the sample for digestion. The samples were allowed to be evenly distributed in the acid by stirring with a glass rod; the beaker was then placed on the digestion block in a fume cupboard for 2 hours at temperature 150°C for digestion. The digested samples were then filtered into a 25 mL volumetric flask and made to mark with deionized water. The digested samples were kept at 4°C prior to analysis. A Solar thermo elemental Atomic Absorption Spectrophotometer (Flame AAS) model S4 71096was used for lead (Pb), cadmium (Cd), nickel (Ni), arsenic (AS), iron (Fe), and copper (Cu) analysis [18].

2.5 Heavy Metal Health Risk Assessment

The potential health risks of heavy metal consumption through vegetables were assessed based on the estimated daily intake of metals (EDI) [19], the target hazard quotient (THQ) [20,21], Hazard index (HI) [22] and the Incremental Lifetime Cancer Risk (ILCR) [23]. The estimated daily intake of metals (EDI) was calculated to averagely estimate the daily metal loading into the body system of a specified body weight of a consumer. This will inform the relative phyto-availability of metal.

2.6 Estimated Daily Intake (EDI)

$$EDI = \frac{C_{metal} X D_{food intake}}{B_{Waverage}}$$

Where:

C_{metal} is the metal concentration in vegetable in mg/kg, D_{food} intake is the daily intake of food in kg/person and $BW_{average}$ is average body weight in kg/person.

An average daily consumption of 0.2 kg of vegetable was assumed in this study [17]. This value was adopted because vegetable constitute a major part of the diet. Average body weight for both adult male and female was considered to be 60 kg and 24 kg for both male and female children [17].

2.7 Non-carcinogenic Health Effect

2.7.1 Target hazard quotient

Non-carcinogenic risk estimation of heavy metals consumption was determined using THQ values [20,21]. Target hazard quotient is a ratio of the determined dose of a toxicant to a reference dose considered harmful [24]. If the ratio is equal to or greater than 1, an exposed population is at risk. THQ values were calculated using the following formula below [20,21]

$$THQ = \frac{EfrXEDXFIRXC}{RfD_O XBWaverageXATn} \times 10^{-3}$$

Where

Efr is exposure frequency in 156 days $year^{-1}$,
ED is the exposure duration (56 years, equivalent to the average lifetime of the Nigerian population)
FIR is average daily consumption in kg $person^{-1}$ day^{-1},
C is concentration of metal in food sample in mg/kg
RfDo is reference dose in mg/kg day^{-1} and [3]
ATn is average exposure time for non–carcinogens in days (156 x 56).

The following reference doses were used (Pb =0.0035 mg/kg; Cd; = 0.001 mg/kg; Ni=0.02 mg/kg; As = 0.050 mg/kg; Fe = 0.700 mg/kg; Cu = 0.040 mg//kg) [25]

2.7.2 Calculation of hazard index

Hazard index (HI) is used to evaluate the potential risk to human health when more than one heavy metal is involved. Hazard index was calculated as the sum of hazard quotients (HQs). Since different pollutants can cause similar adverse health effects, it is often appropriate to combine HQs associated with different substances.

$HI = \Sigma THQ (THQ_1+THQ_2+THQ_3 \ldots\ldots\ldots THQ_n)$

2.7.3 Carcinogenic risk (CR)

Incremental lifetime cancer risk (ILCR) is the lifetime probability of an individual developing any type of cancer due to carcinogenic daily exposure to a contaminant over a life time [26]. The ILCR is obtained using the Cancer Slope Factor (CSF) which evaluates the probability of an individual developing cancer from oral exposure to contaminant levels over a period of a lifetime of 1 mg/kg BW/day and is contaminant specific [27]. Therefore, ILCR value in vegetable evaluates the probability of an individual developing cancer from oral exposure to contaminant levels over a period of a lifetime [28]. Ingestion cancer slope factors are expressed in units of (mg/kg/day).

The cancer risk was calculated using the equation below;

Carcinogenic risk=EDI × CSF_{ing}

Where:

EDI is the estimated daily intake of each heavy metal (mg/kg/day)
CSF_{ing} is ingestion cancer slope factor $(mg/kg/day)^{-1}$ (Pb=0.0085, Cd=0.38, Ni=0.91, and As =1.5) [29,30].

United State Environmental Protection Agency [31] states that 10^{-6} (1 in 1,000,000) to 10^{-4} (1 in 10,000) represent a range of permissible predicted lifetime risks for carcinogens. Chemical for which the risk factor falls below 10^{-6} may be eliminated from further consideration as a chemical of concern.

3. RESULTS

The results of different vegetable samples analyzed for Pb, Cd, Ni, As, Fe and Cu are shown in Table 2. The results from the present study showed that the mean concentrations of total Pb, Cd, Ni, As, Fe, and Cu in edible portions of vegetables ranges between 0.168-4.908, 0.364-2.977, 2.780-10.241, 0.157-2.633, 61.589-101.520, and 12.033-46.536 mg/kg, respectively.

The average concentrations of heavy metals in all the analyzed vegetable samples were in the order of Fe > Ni > Cu > As >Pb> Cd. The coefficients of variation for the six heavy metals in the analyzed vegetables also followed the same order.

The highest level of Pb was recorded in *T. triangulare*(4.908 ± 0.012 mg/kg) from Elleta community, while the lowest level of Pb was recorded in *T. triangulare* (0.168 ± 0.003 mg/kg) from Okposi community.

The highest level of Cd was observed in *V. amygdalina* (2.977 ± 0.02 mg/kg) from Obrikom community. However, *A. esculentus* from Obrikom community was below detectable limit.

The highest concentration of Ni was observed in *T. occidentalis* (10.241 ± 0.11 mg/kg) from Elleta community, *T. triangulare* from Omoku community and *A. esculentus* from Elleta community were below detectable limit.

The highest concentration of As was recorded in *T. occidentalis* (2.633 ± 0.006 mg/kg) from Elleta community. However, *A. esculentus* from Okposi community was below detectable limit.

The highest concentration of Fe was observed in *A. esculentus* (101.520 ± 0.004 mg/kg) from Omoku community while the lowest level was recorded in *V. amygdalina*(61.589 ± 0.010 mg/kg) from Okposi community.

The highest concentration of Cu was recorded in *T. triangulare* (46.536 ± 0.006 mg/kg) from Omoku community while the lowest level was recorded in *A. esculentus* (12.033 ± 0.004 mg/kg) from Okposi community.

3.1 Estimated Daily Intake (EDI) of Metals in (mg/kg) for Adult Population

The results of the EDI of metals in the adult population was shown in Table 3. The EDI result of Pb was within the range of 0.001 to 0.016 mg/kg. The highest EDI value of Pb was observed in *T. triangulare* (0.016 mg/kg) from Elleta community while the lowest values were recorded in *T. occidentalis* (0.001 mg/kg) from Omoku community, *V. amygdalina* (0.001 mg/kg), *T. triangulare* (0.001 mg/kg), *T. occidentalis* (0.001 mg/kg) all from Okposi community and *A. esculentus* (0.001 mg/kg) from Elleta community.

The EDI values of Cd ranged between 0.001 to 0.010 mg/kg with the highest value recorded in *V. amygdalina* (0.010 mg/kg) from Obrikom community. However, concentrations of *A. esculentus* from Obrikom community and *T. triangulare* from Okposi community were below detectable limits. The EDI result of Ni was within the range of 0.009 to 0.034 mg/kg with *T. occidentalis* from Elleta community recording the highest value (0.034 mg/kg) while *T. triangulare* from Omoku community and *A. esculentus* from Elleta community were below detectable limits (BDL < 0.001).

The EDI values of As ranged between 0.001 to 0.008 mg/kg. The highest value was observed in *T. triangulare* (0.008 mg/kg) from Omokucommunity, however *A. esculentus* from Okposi community was below detectable limit.

The EDI values of Fe ranged between 0.205 to 0.338 mg/kg with the highest value recorded in *V. amygdalina*(0.338 mg/kg) from Elleta community while the lowest value was observed in *V. amygdalina*(0.205 mg/kg) from Okposi community.

Table 2. Concentration of heavy metals in mg/kg in selected vegetable samples in ONELGA

Location	Sample	Pb	Cd	Ni	As	Fe	Cu
Obrikom	*V. amygdalina*	1.634 ± 0.012	2.977 ± 0.02	3.848 ± 0.003	1.364 ± 0.02	86.902 ± 0.016	43.604 ± 0.005
	T. triangulare	3.824 ± 0.021	0.394 ± 0.05	2.963 ± 0.009	0.385 ± 0.005	78.766 ± 0.04	21.109 ± 0.01
	A. esculentus	0.773 ± 0.033	BDL	2.889 ± 0.01	1.782 ± 0.002	81.866 ± 0.05	19.526 ± 0.003
	T. occidentalis	1.375 ± 0.011	0.855 ± 0.013	4.158 ± 0.05	0.566 ± 0.047	90.494 ± 0.005	38.443 ± 0.006
Omoku	*V. amygdalina*	2.294 ± 0.005	1.816 ± 0.012	6.565 ± 0.04	0.656 ± 0.006	92.924 ± 0.003	36.109 ± 0.003
	T. triangulare	2.373 ± 0.001	0.825 ± 0.006	BDL	2.384 ± 0.006	84.374 ± 0.007	46.536 ± 0.006
	A. esculentus	0.567 ± 0.009	0.494 ± 0.02	3.456 ± 0.02	1.634 ± 0.01	96.617 ± 0.02	14.838 ± 0.005
	T. occidentalis	0.381 ± 0.007	1.454 ± 0.006	4.206 ± 0.01	0.374 ± 0.02	80.727 ± 0.006	23.244 ± 0.005
Okposi	*V. amygdalina*	0.413 ± 0.006	1.533 ± 0.003	8.177 ± 0.03	0.567 ± 0.01	61.589 ± 0.010	28. 258 ± 0.005
	T. triangulare	0.168 ± 0.003	BDL	5.542 ± 0.06	1.478 ± 0.01	63.591 ± 0.007	42.394 ± 0.005
	A. esculentus	2.894 ± 0.005	0.724 ± 0.02	4.933 ± 0.007	BDL	72.127 ± 0.005	12.033 ± 0.004
	T. occidentalis	0.255 ± 0.005	1.345 ± 0.03	2.780 ± 0.02	0.782 ± 0.01	75.642 ± 0.008	26.247 ± 0.005
Elleta	*V. amygdalina*	1.860 ± 0.009	0.761 ± 0.009	8.166 ± 0.02	0.297 ± 0.006	101. 520 ± 0.004	24.394 ± 0.005
	T. triangulare	4.908 ± 0.012	1.545 ± 0.003	7.441 ± 0.009	0.474 ± 0.01	88.955 ± 0.01	15.407 ± 0.003
	A. esculentus	0.234 ± 0.016	0.364 ± 0.006	BDL	0.157 ± 0.004	95.515 ± 0.01	33.492 ± 0.003
	T. occidentalis	1.128 ± 0.005	1.536 ± 0.003	10.241 ± 0.11	2.633 ± 0.006	74.538 ± 0.009	42.611 ± 0.007

The EDI values of Cu ranged between 0.040 to 0.155 mg/kg with the highest value recorded in *T. triangulare* (0.155 mg/kg) from Omoku Community while the lowest value was observed in *A. esculentus* (0.040 mg/kg) from Okposi community.

- ❖ Recommended tolerable daily intake (TDI) and upper tolerable daily intake (UTDI) levels of heavy metals in food stuffs [32,33].

3.2 Estimated Daily Intake (EDI) of Metals in (mg/kg) For Children Population

The results of the EDI of metals in the children population are shown in Table 4. The EDI values of Pb ranged between 0.001 to 0.041 mg/kg. Calculated EDI for Pb in children was highest in *T. Triangulare* (0.041 mg/kg) from Elleta community.

The EDI values of Cd ranged from 0.003 to 0.025 mg/kg with *V. amygdalina* from Obrikom community recording the highest value (0.025 mg/kg).

Calculated EDI for Ni ranged between 0.023 to 0.085 mg/kg with the highest value recorded in *T. occidentalis* (0.085 mg/kg) from Elleta community.

The EDI values of As ranged between 0.001 to 0.022 mg/kg with *T. occidentalis*from Elleta community recording the highest EDI value (0.022 mg/kg).

Calculated EDI for Fe in children ranged between 0.513 to 0.846 mg/kg with the highest value recorded in *V. amygdalina* (0.846 mg/kg) from Elleta community.

The EDI for Cu in children ranged between 0.100 to 0.388 mg/kg with the highest value recorded in *T. triangulare* from Omoku community.

- Recommended tolerable daily intake (TDI) and upper tolerable daily intake (UTDI) levels of heavy metals in food stuffs [32,33].

3.3 Target Hazard Quotient (THQ) and Hazard Index (HI) of Heavy Metals for Adult and Children Population

The Target hazard quotient (THQ) value greater than 1 indicates health concern. The non-carcinogenic risk of six heavy metals exposure to consumption of vegetables from four communities in ONELGA, Rivers State are presented in Tables 5 and 6.

The THQ value for Pb ranged from 0.156 to 4.690 mg/kg with the highest value recorded in *T. triangulare* (4.690 mg/kg) from Elleta community in adult whereas calculated THQ value for Pb in children ranged between 0.390 to 11.726 mg/kgwith *T. triangulare* (11.726 mg/kg) from Elleta community recording the highest value.

Table 3. Estimated daily intake (EDI) of heavy metals in mg/kg for adult (60 kg) population in ONELGA via consumption of vegetables

Location	Samples	Pb	Cd	Ni	As	Fe	Cu
OBRIKOM	*V. amygdalina*	0.005	0.010	0.013	0.005	0.290	0.145
	T. triangulare	0.013	0.0013	0.010	0.001	0.263	0.070
	A. esculentus	0.003	0	0.010	0.006	0.273	0.065
	T. occidentalis	0.005	0.003	0.014	0.002	0.302	0.128
OMOKU	*V. amygdalina*	0.008	0.006	0.022	0.002	0.310	0.120
	T. triangulare	0.008	0.002	0	0.008	0.281	0.155
	A.esculentus	0.002	0.002	0.012	0.006	0.322	0.050
	T. occidentalis	0.001	0.005	0.014	0.001	0.269	0.078
OKPOSI	*V. amygdalina*	0.001	0.005	0.027	0.002	0.205	0.094
	T. triangulare	0.001	0	0.018	0.002	0.212	0.141
	A. esculentus	0.010	0.002	0.016	0	0.240	0.040
	T. occidentalis	0.001	0.004	0.009	0.003	0.252	0.088
ELLETA	*V. amygdalina*	0.006	0.003	0.027	0.001	0.338	0.081
	T. triangulare	0.016	0.005	0.025	0.002	0.297	0.051
	A. esculentus	0.001	0.001	0	0.001	0.318	0.112
	T. occidentalis	0.004	0.005	0.034	0.009	0.249	0.142

Table 4. Estimated daily intake (EDI) of heavy metals mg/kg for children (24 kg) population in ONELGA via consumption of vegetables

Location	Samples	Pb	Cd	Ni	As	Fe	Cu
OBRIKOM	*V. amygdalina*	0.014	0.025	0.032	0.011	0.724	0.363
	T. triangulare	0.032	0.003	0.025	0.003	0.656	0.176
	A. esculentus	0.006	0	0.024	0.015	0.683	0.163
	T. occidentalis	0.012	0.007	0.035	0.005	0.754	0.320
OMOKU	*V. amygdalina*	0.019	0.015	0.055	0.005	0.774	0.301
	T. triangulare	0.020	0.007	0	0.020	0.703	0.388
	A. esculentus	0.005	0.004	0.029	0.014	0.805	0.124
	T. occidentalis	0.003	0.012	0.023	0.003	0.673	0.194
OKPOSI	*V.amygdalina*	0.003	0.013	0.068	0.005	0.513	0.236
	T. triangulare	0.001	0	0.046	0.012	0.530	0.353
	A. esculentus	0.024	0.006	0.041	0	0.601	0.100
	T. occidentalis	0.002	0.011	0.023	0.006	0.630	0.219
ELLETA	*V. amygdalina*	0.016	0.006	0.068	0.003	0.846	0.203
	T. triangulare	0.041	0.013	0.062	0.004	0.741	0.128
	A. esculentus	0.002	0.003	0	0.001	0.796	0.279
	T. occidentalis	0.009	0.013	0.085	0.022	0.621	0.355

The THQ values of Cd ranged between 1.205 to 9.937 mg/kg and 3.012 to 24.838 mg/kg for adult and children population respectively. However, *V. amygdalina* from Obrikom community recorded the highest THQ values of 9.937 and 24.838 mg/kgfor adult and children population respectively.

The THQ value for Ni ranged between 0.461 to 1.701mg/kgand 1.151 to 4.252 mg/kgfor adults and children respectively. However, the highest values in adults and children were seen in *T. occidentalis* (1.701 mg/kg and 4.252 mg/kg) both from Elleta community.

The THQ value of As was within the range of 8.69E-06to 0.271 mg/kg and 6.94E-07to 1.10E-05mg/kg for adults and children respectively. The highest THQ values for As in the adult and children population were recorded in *V. amygdalina* (0.271 mg/kg) from Elleta community and in *T. triangulare* (1.10E-05) respectively.

The THQ value of Fe ranged between 0.293 to 0.483mg/kgand 0.733 to 1.209mg/kgfor adults and children population respectively. The highest value was recorded in *V. amygdalina* (0.483 and 1.209 mg/kg) both from Elleta community in adults and children respectively.

The THQ value of Cu was within the range 1.003 to 3.878 mg/kg and 2.507 to 9.693 mg/kgfor adults and children population respectively. The highest value was recorded in *T. triangulare*(3.877 and 9.693 mg/kg) from Omoku community in both adult and children population respectively.

The result of the Hazard Index (HI) of adult and children population from all the communities shown in Tables 5 and 6 ranged between 3.223 to 16.185 mg/kg and 8.060 to 40.420 mg/kg for adult and children population respectively.

The highest HI value in adult population was recorded in *V. amygdalina* (16.185 mg/kg) whereas the highest HI value in children was recorded in *V. amygdalina* (40.420 mg/kg) both from Obrikom community.

3.4 Carcinogenic Risk (CR) for Adult and Children Population

The results in Tables 7 and 8 shows the Life Cancer Risk of vegetables exposed to heavy metals contamination over a life time for adult and children population respectively. The LCR value for Pb, Cd, Ni, and As in adult population ranged between 8.5E-06 to 1.11E-04 mg/kg/day, 7.6E-04 to 0.004 mg/kg/day, 0.015 to 0.058 mg/kg/day, and 0.002 to 0.014 mg/kg/day respectively having their highest values at *T. triangulare* (1.11E-04 mg/kg/day), *V. amygdalina* (0.004 mg/kg/day) both from Obrikom community, *T. occidentalis* (0.058 mg/kg/day), and *T. occidentalis* (0.014 mg/kg/day) both from Elleta community respectively. Meanwhile, the LCR for Pb, Cd, Ni, and As in children population ranged from (8.5E-06 to 1.02E-04mg/kg/day), (0.001 to 0.095 mg/kg/day), (0 039 to 0.145 mg/kg/day), and (0.002 to 0.033 mg/kg/day) respectively having their highest values at *T. occidentalis* (1.02E-04 mg/kg/day), *V. amygdalina* (0.0095 mg/kg/day) both from Obrikom community, *T. occidentalis* (0.145 mg/kg/day), and *T. occidentalis* (0.033 mg/kg/ day) both from Elleta community respectively.

4. DISCUSSION

Heavy metals contamination in soil from various anthropogenic sources such as Industrial wastes, waste water irrigation, air deposition, oil spillage from oil exploration, automobile emissions, mining activity, and agricultural practices are believed to easily accumulate in the top soil whichresults to bioaccumulation, bio magnification and geo accumulation of the heavy metals in different parts of the plants especially the vegetables [3,34,35]. As a result of sewage water irrigation, high level of oil exploration, application of phosphate fertilizers, sewage sludge application, etc., accumulation of heavy metals in vegetables may be increased [36].This can easily enter the food chain thereby causing different diseases. The intake of these edible vegetables contaminated with heavy metals may result to intoxication that can be described as acute or when the disease appears after a potential period of time and long term or chronic intoxications [9]. It was described in previous studies that leafy vegetables have higher concentration of metals as compared to bulbs and tuber vegetables due to smoke emitted from industries present in vicinity of vegetables [37]. Ingestion of contaminated food is the main route of human exposure to these toxic compounds accounting for more than ninety percent compared to other routes [11,12]. Higher concentration of these heavy metals is the outcome of industrial pollution, oil exploitation, road runoff, food, wear of tires, hospital waste, atmospheric deposition and burning of fuels [38].

Table 5. Target hazard quotient (THQ) and hazard index (HI) for adults exposed to vegetables contaminated with heavy metals in ONELGA

Location	Samples	Pb	Cd	Ni	As	Fe	cu	Hazard Index (HI)
OBRIKOM	*V. amygdalina*	1.544	9.937	0.641	0.015	0.414	3.634	16.185
	T. triangulare	3.640	1.314	0.493	4.28E-06	0.375	1.758	7.580
	A. esculentus	0.724	0	0.482	1.98E-05	0.390	1.627	3.223
	T. occidentalis	1.314	2.804	0.695	6.29E-06	0.431	3.203	8.447
OMOKU	*V. amygdalina*	2.185	6.001	1.089	7.29E-06	0.443	3.009	12.727
	T. triangulare	2.259	2.763	0	2.65E-05	0.402	3.877	9.301
	A. esculentus	0.535	1.645	0.577	1.82E-05	0.460	1.236	4.453
	T. occidentalis	0.364	4.869	0.699	4.16E-06	0.384	1.937	8.253
OKPOSI	*V. amygdalina*	0.389	5.098	1.357	6.3E-06	0.293	2.355	9.492
	T. triangulare	0.156	0	0.919	1.64E-05	0.303	3.533	4.911
	A. esculentus	2.757	2.405	0.821	0	0.343	1.003	7.330
	T. occidentalis	0.245	4.351	0.461	8.69E-06	0.360	2.187	7.604
ELLETA	*V. amygdalina*	1.774	2.544	1.357	0.271	0.483	2.033	8.462
	T. triangulare	4.690	5.131	1.235	1.71E-04	0.424	1.284	12.764
	A. esculentus	0.232	1.205	0	3.72E-04	0.455	2.791	4.678
	T. occidentalis	1.075	5.122	1.701	4.74E-04	0.355	3.551	11.804

Table 6. Target hazard quotient (THQ) and hazard index (HI) for children exposed to vegetables contaminated with heavy metals in ONELGA

Location	Samples	Pb	Cd	Ni	As	Fe	Cu	Hazard Index (HI)
OBRIKOM	*V. amygdalina*	3.860	24.838	1.603	6.28E-06	1.035	9.084	40.420
	T. triangulare	9.091	3.285	1.232	1.78E-06	0.937	4.396	18.941
	A. esculentus	1.811	0	1.206	3.3E-06	0.975	4.068	8.060
	T. occidentalis	3.284	7.009	1.739	2.53E-06	1.077	8.008	21.117
OMOKU	*V. amygdalina*	5.462	14.999	2.722	2.97E-06	1.106	7.522	31.811
	T. triangulare	5.647	6.907	0	1.10E-05	1.004	9.693	23.251
	A. esculentus	1.338	4.113	1.443	7.50E-06	1.150	3.091	11.135
	T. occidentalis	0.901	12.171	1.747	1.42E-06	0.961	4.842	20.622
OKPOSI	*V. amygdalina*	0.972	12.742	3.392	2.58E-06	0.733	5.887	23.726
	T. triangulare	0.390	0	2.297	6.81E-06	0.757	8.832	12.276
	A. esculentus	6.894	6.012	2.052	0	0.859	2.507	18.323
	T. occidentalis	0.613	10.875	1.151	1.42E-06	0.900	5.467	19.006
ELLETA	*V. amygdalina*	4.434	6.359	3.393	1.39E-06	1.209	5.081	20.476
	T. triangulare	11.726	12.826	3.088	2.14E-06	1.059	3.210	31.986
	A. esculentus	0.581	3.012	0	6.94E-07	1.137	6.978	11.708
	T. occidentalis	2.688	12.803	4.252	1.22E-05	8.888	8.878	37.509

Table 7. Life cancer risk (LCR) table for adult population

Locations	Samples	Pb	Cd	Ni	As	Fe	Cu
OBRIKOM	*V. amygdalina*	4.25E-05	0.004	0.022	0.008	-	-
	T. triangulare	1.11E-04	4.94E-04	0.017	0.002	-	-
	A. esculentus	2.55E-05	0	0.017	0.009	-	-
	T. occidentalis	4.25E-05	0.001	0.024	0.003	-	-
OMOKU	*V. amygdalina*	6.8E-05	0.002	0.037	0.003	-	-
	T. triangulare	6.8E-05	7.6E-04	0	0.012	-	-
	A. esculentus	1.7E-05	7.6E-04	0.020	0.009	-	-
	T. occidentalis	8.5E-06	0.002	0.024	0.002	-	-

Locations	Samples	Pb	Cd	Ni	As	Fe	Cu
OKPOSI	*V. amygdalina*	8.5E-06	0.002	0.046	0.003	-	-
	T. triangulare	8.5E-06	0	0.031	0.003	-	-
	A. esculentus	8.5E-05	7.6E-04	0.027	0	-	-
	T. occidentalis	8.5E-06	0.002	0.015	0.005	-	-
ELLETA	*V. amygdalina*	5.1E-05	0.001	0.046	0.002	-	-
	T. triangulare	1.36E-04	0.002	0.043	0.003	-	-
	A. esculentus	8.5E-06	3.8E-04	0	0.002	-	-
	T. occidentalis	3.4E-05	0.002	0.058	0.014	-	-

Table 8. Life Cancer Risk (LCR) Table for Children Population

Locations	Samples	Pb	Cd	Ni	As	Fe	Cu
OBRIKOM	*V. amygdalina*	1.19E– 04	0.0095	0.054			
	T. triangulare	2.72E-04	0.001	0.043	0.005	-	-
	A. esculentus	5.1E-05	0	0.041	0.023	-	-
	T. occidentalis	1.02E-04	0.003	0.060	0.008	-	-
OMOKU	*V. amygdalina*	1.62E-04	0.006	0.094	0.008	-	-
	T. triangulare	1.7E-04	0.003	0	0.03	-	-
	A. esculentus	4.25E-05	0.002	0.049	0.021	-	-
	T. occidentalis	2.55E-05	0.005	0.039	0.005	-	-
OKPOSI	*V. amygdalina*	2.55E-05	0.005	0.116	0.008	-	-
	T. triangulare	8.5E-06	0	0.078	0.018	-	-
	A. esculentus	2.04E-04	0.002	0.070	0	-	-
	T. occidentalis	1.7E-05	0.004	0.039	0.009	-	-
ELLETA	*V. amygdalina*	1.36E-04	0.002	0.116	0.005	-	-
	T. triangulare	3.49E-04	0.005	0.105	0.006	-	-
	A. esculentus	1.75E-05	0.001	0	0.002	-	-
	T. occidentalis	7.65E-05	0.005	0.145	0.033	-	-

The present study has highlighted the contamination profile of vegetables commonly consumed from selected communities in Ogba/Egbema/Ndoni Local Government Area in Rivers State, Nigeria and the possible public health implications.

The concentrations of Pb in *T. triangulare* (3.824 mg/kg) from Obrikom community, *V. amygdalina* (2.294 mg/kg), *T. triangulare* (2.373 mg/kg) from Omoku community, *A. esculentus* (2.894 mg/kg) from Okposi community and *T. triangulare* (4.908 mg/kg) from Elleta community, respectively were higher than the 2.0 mg/kg value as recommended by FAO/WHO [39].

Almost all the samples analyzed for Pb were above the 0.3 mg/kg as recommended by European communities [40]. All the analyzed samples of Pb were higher than the 0.2 mg/kg recommendedby China [41] except for *T. triangulare* (0.164 mg/kg) from Okposi community. These were similar to the results obtained by Asdeo and Loonker [42] where the Pb accumulation in vegetables was found to be within the range of 2.32 to 5.76 mg/kg. The high levels of Pb in these vegetables may probably be attributed to pollutants in irrigation water, farm soil (farm site) contaminated by crude oil from oil exploration or due to pollution from the highways traffic [43,34].

High concentration of Pb could be due to increase in mobile metal fraction of Pb and high level of oil exploration [44] with higher metal fraction, uptake and accumulation of metal in vegetable increase.

There were lower levels of Pb in *T. triangulare* (0.168 mg/kg), *T. occidentalis* (0.255 mg/kg) both from Okposi community and *A. esculentus* (0.234 mg/kg) from Elleta community as reported by Agrawal [45]. Lower levels of Pb have been reported in *T. occidentalis* by Akinola and Ekiyoyo [46].

Lead is known to induce reduced cognitive development and intellectual performance in children and cardiovascular disease and increased blood pressure in adults [41].

Generally, Pb contaminations occur in vegetables grown in contaminated soils, through air deposition, sewage sludge/waste water application or oil exploration [34]. In human body, Pb causes neurological, hematological and physiological disorders [38]. Lead influences the nervous system, slowing down nervous response. This influences learning abilities and behavior [35].

The concentration of Cd in all the samples from the four communities exceeded the permissible limit of 1.0 mg/kg and 0.2 mg/kgrecommended by WHO/FAO and European Commission [40,47] except for *A. esculentus* and *T. triangulare* from Obrikom and Okposi community respectively, which were below detectable limit.

Lower values have been reported for leafy vegetables cultivated along road sides (0.27 mg/kg) and leafy vegetables obtained from four markets (0.20 mg/kg) in Lagos State [34,48]. Low level of cadmium may be attributed to low or no use of phosphate fertilizers by the farmers on the planted vegetables.

The higher level of cadmium in the present study may be attributed to high use of phosphate fertilizers by the farmers in the study area which tend to increase the accumulation of cadmium in the soil. Cadmium is a heavy metal with high toxicity and it is a non-essential element in foods and natural waters and it accumulates principally in the kidney and liver [49,35]. Accumulation of Cd in human body leads to certain disorder including cardiovascular diseases, liver and nervous systemdiseases [49,35]. The most common sources of Cd in plants and vegetables are sewage sludge application, deposition from fossil fuel combustion, phosphate fertilizers etc. [35].

Cadmium accumulates especially in the kidney leading to dysfunction of the kidney with increased secretion ofe.g proteins in urine (proteinuria) and other effects [50].

The highest level of Ni was recorded in *T. occidentalis* (10.241 mg/kg) from Elleta community while *T. occidentalis* (2.780 mg/kg) from Okposi community recorded the least Ni concentration. In this study, Ni concentration in all the analyzed samples exceeded the permissible limit of 2.7 mg/kg recommended by NAFDAC except *T. triangulare* and *A. esculentus* from Omoku and Elleta communities respectively which were below detectable limit.

Nickel concentration in vegetables were lower than the estimated maximum guideline set by US FDA of 70-80 mg/kg [51]. This was contrary to Adedokun, et al. [48] who reported a lower level of Ni, this could be attributed to lack of oil exploration in that area as compared with the high rate of oil exploration by oil companies in ONELGA. Inhaled Ni carbonyl, a carcinogenic gas that results from the action of nickel with heated carbon monoxide from cigarette smoke, car exhaust, and some industrial wastes is very toxic and Ni allergy can also cause systematic reactions [52].

The concentration of the metalloid, As in over 80% of the samples from all the selected communities exceeded the permissible limit of 0.43 mg/kg recommended by WHO/FAO [39]. This was in line with Jun Yang, *et al* [53]who reported high level of As concentration in the soil of Daye city of Hubei Province, China. This may be attributed to the contamination of the soil by oil spillage caused by excessive oil exploration by oil companies, pipeline vandalization etc.

Lower levels of As were obtained from *T. triangulare* (0.385 mg/kg), *T. occidentalis* (0.374 mg/kg), *V. amygdalina* (0.297 mg/kg) and *A. esculentus* (0.157 mg/kg) from Obrikom, Omoku and Elleta communities respectively, while *A. esculentus* from Okposi community was below detectable limit. Arsenic has been classified as a human carcinogen, with chronic ingestion associated with lung cancer [54]. It has been suggested that exposure to arsenic-rich food increases the risk of cardiovascular disease, hypertension and diabetes mellitus [55].

Iron is essential for the synthesis of chlorophyll and activates a number of respiratory enzymes in plants. The deficiency of Fe results in severe chlorosis of leaves in plants. High levels of exposure to Fe dust may cause respiratory diseases such as chronic bronchitis and ventilation difficulties. The Fe contents of these vegetables in the present study were lower than the FAO/WHO safe limit of 425.00 mg/kg [39]. These vegetables could be good supplement for Fe. From the six heavy metals analyzed, the concentration of Fe in *V. amygdalina*(101 mg/kg) was the highest, suggesting that Fe is more susceptible to the interference of vegetable species, pollution and other external factors from the present study.

The concentration of Cu in the analyzed samples were within the permissible level of 73.00 mg/kg by the FAO/WHO [39] in vegetables. Also, about 80% of all the samples from the four communities were within the suggested safe limits of 40 mg/kg recommended by joint Expert Committee for Food Additives (JECFA) [56] for foodstuffs except for *V. amygdalina* (43.604 mg/kg) from Obrikom community, *T. triangulare* (46.536 mg/kg) from Omoku community, *T. triangulare* (42.394 mg/kg) from Okposi and in *T. occidentalis* (42.611 mg/kg) from Elleta communities which were slightly higher than the suggested safe limits of 40mg/kg as recommended by JECFA [56]. However the Cu levels obtained from this present study were higher than that of Adedokun et al. [48] where the concentration of Cu ranged between (2.338 mg/kg) in *T. occidentalis* to (14.075 mg/kg) in *T. triangulare* in the vegetables they worked with.

Copper is essential to human life as metalloproteins and function as enzymes, however, critical doses leads to health risks such as anemia, diabetes, inflammation, kidney and liver dysfunction and vitamin c deficiency [57]. Although toxicity is rare, it's metabolism is enhanced by Molybdenum and Zinc constituents in the body [58].

4.1 Estimated Daily Intake (EDI) of Metals in (mg/kg) for Adult Population

The EDI results in adult population were compared with the recommended tolerable daily intake of metals (TDI) and the upper tolerable daily intake level (UTDI) established by the Institute of medicine [59].

The EDI result of Pb (0.001 to 0.016 mg/kg) and Cd (0.001 to 0.005 mg/kg) exceeded the recommended tolerable daily intake of metals (TDI) but fall within the upper tolerable daily intake (UTDI). However, Ni (0.009 to 0.034 mg/kg), Fe (0.205 to 0.338 mg/kg) and Cu (0.040 to 0.155 mg/kg) were lower than the recommended tolerable daily intake of metals (TDI) and the upper tolerable daily intake level (UTDI).

Arsenic (0.001 to 0.009 mg/kg) exceeded the recommended tolerable daily intake of metals (TDI) and some of the analyzed samples from different locations such as *V. amygdalina* (0.005 mg/kg), *A. esculentus* (0.006 mg/kg) both from Obrikom community, *T. triangulare* (0.008 mg/kg), *A. esculentus* (0.006 mg/kg) both from Omoku community, *T. occidentalis* (0.003 mg/kg) from Okposi community and *T. occidentalis* (0.009 mg/kg) from Elleta community exceeded the upper tolerable daily intake level (UTDI) whereas the other analyzed samples fall within the upper tolerable daily intake level (UTDI).

4.2 Estimated Daily Intake (EDI) of Metals in (mg/kg) for Children Population

The EDI result of Pb (0.001 to 0.041 mg/kg) and Cd (0.003 to 0.025 mg/kg) exceeded the recommended tolerable daily intake of metals (TDI) but fall within the upper tolerable daily intake level (UTDI). Similarly, like the EDI result in the adult population, Ni (0.023 to 0.85 mg/kg), Fe (0.513 to 0.84 mg/kg), and Cu (0.100 to 0.388 mg/kg) were lower than the recommended tolerable daily intake (TDI) and the upper tolerable daily intake level (UTDI), except for *A. esculentus* (0.001 mg/kg) from Elleta community which falls within the upper tolerable daily intake level (UTDI).

4.3 Target Hazard Quotient (THQ) of Heavy Metals for Adult and Children Population

The THQ is a ratio between the measured concentration and the oral reference dose, weighted by the length and frequency of exposure; amount ingested and body weight [24]. From the results of the present study in adult population, the THQ values of Pb in some of the samples in adult population most notably in *T. triangulare* (4.690mg/kg) from Elleta community were greater than 1.

Almost all the samples analyzed for Cd were greater than 1 except for *A. esculentus* from Obrikom community which was below detectable limit (BDL < 0.001) and it is highest in *V. amygdalina* (9.937 mg/kg) from Obrikom community.

The THQ values of Nickel were mostly less than 1 but highest in *T. occidentalis* (1.701mg/kg) from Elleta community. The THQ values of As and Fe were less than 1 which indicates that the population may not be at risk of As and Fe contamination and toxicity.

The THQ values of Cu in all the analyzed samples were all greater than 1 most notably in *V. amygdalina* (3.634mg/kg) from Obrikom community in adult population.

The result for THQ in the children population in the present study shows that THQ values of Pb were mostly greater than 1 and is highest in *T. triangulare* (11.726 mg/kg) from Elleta community.

The THQ values of Cd in most of the samples were greater than 1 most notably in *V. amygdalina* (24.838 mg/kg) from Obrikom community.

The THQ values of Ni in the analyzed samples were mostly greater than 1 and highest in in *T. occidentalis* (4.252 mg/kg) from Elleta community.

The THQ values of As in the analyzed samples were all less than 1 which indicates that the population may not be at risk of As contamination from the consumption of vegetables in the present study.

The THQ values of Fe in all the analyzed samples were mostly greater than 1 and a good portion of Fe in the samples were less than 1 and was highest in *V. amygdalina* (1.209 mg/kg) from Elleta community. The THQ values of Cu in the analyzed samples were all greater than 1 and is highest in *T. triangulare* (9.693mg/kg) from Omoku community.

From the result of the present study for adult population, the THQ of Cu, Cd, and Pb in all the analyzed samples were mostly greater than 1, which indicates that the adult population of ONELGA in Rivers State may be at risk of Cu, Cd, and Pb contamination and toxicity.

The THQ values of As and Fe in the analyzed samples were all less than 1 which indicates that the adult population may not be at risk of As and Fe contamination and toxicity in the present study, also, the THQ values of Ni in most of the analyzed samples were mostly less than 1, which also indicates that Ni may not be a metal of concern for the adult population in the present study. The adult and children population were highly exposed to health risks associated to these metals in the order Cu>Cd>Pb>Ni>Fe>As for the adult population and Cu>Cd>Ni> Pb>Fe>As for the children population in the present study.

The result of the THQ in children population shows that the THQ of Cu, Cd, Ni, Pb, and slightly Fe were mostly greater than 1, which indicates level of concern that the children population may be at risk of Cu, Cd, Ni, Pb, and slightly Fe contamination and toxicity from vegetables consumption. The THQ of As in all the samples were all less than 1 which indicates that there may not be health concern of As contamination and toxicity for the children in the present study.

Generally, the present study has shown that both the adult and children population have a THQ greater than 1 which indicates that there may be health concerns for the adult and children population. Similar THQ for Pb, Cd, and Ni were reported by Singh et al. [3] in vegetables from waste water irrigated area.

The result of the present study has highlighted the various concentrations of the heavy metals of interest in various vegetable samples and it has shown that out of the six metals analyzed, only the metalloid, As in both adults and children population have their THQ less than 1 which indicates that the exposed population may not be at risk of As contamination and toxicity. The other five metals namely; Pb, Cd, Ni, Fe and Cu have THQ values greater than 1 which indicates that the exposed population in ONELGA in Rivers State may be at risk of Cu, Cd, Ni, Pb and Fe contamination and toxicity due to the frequent consumption of these edible vegetables.

4.4 Hazard Index (HI) of Metals for Adult and Children Population

From the result of the present study, the HI in the adult and children population in the analyzed vegetable samples were greater 1). Generally HI < 1 means that the exposed population is safe from heavy metals toxicity whereas HI >1 means that the population may be at risk of heavy metals contamination and toxicity [22]. The population is therefore at greater risk of Pb, Cd, Ni, As, Fe, and Cu as also reported by Tsafe et al. [60]. Generally, it was observed that the health risk for children was higher than that of the adults, which could be due to the difference inbody weight.

4.5 Life Cancer Risk (LCR) for Adult Population

Carcinogenic Risk (CR) also known as Lifetime cancer risk (LCR) is the lifetime probability of an individual developing any type of cancer due to carcinogenic daily exposure to a contaminant over a life time. The LCR is obtained using the Cancer Slope Factor (CSF) which evaluates the probability of an individual developing cancer from oral exposure to contaminant levels over a period of a lifetime as described by ATSDR [61] and it is contaminant specific [27]. Ingestion cancer slope factors are expressed in units of (mg/kg/day). United State Environmental Protection Agency [31] states that 10^{-6} (1 in 1,000,000) to 10^{-4} (1 in 10,000) represent a range of permissible predicted lifetime risks for carcinogens. Chemical for which the risk factor falls below 10^{-6} may be eliminated from further consideration as a chemical of concern.

The Life Cancer Risk (LCR) result in adult population shown in Table 6 showed that the LCR of Pb which ranged from (8.5 E-06 to 1.11 E-04 mg/kg/day) were all within the range of permissible predicted lifetime risks for carcinogens as suggested by USEPA [31]. This indicates that there may be risk of developing any type of cancer due to carcinogenic ingestion and exposure to Pb over time.

The LCR of Cd which ranged from (7.6 E-04 to 0.004 mg/kg/day) showed that almost all the analyzed vegetable samples exceeded the range of permissible predicted lifetime risks for carcinogens as suggested by USEPA [31]. This finding in this study is an indication that there may not be risk of developing any type of cancer due to the carcinogenic ingestion and exposure to Cd over time in the analyzed samples from these locations. However, *T. triangulare* (4.94 E-04 mg/kg/day) from Obrikom community, *T. triangulare* (7.6 E-04 mg/kg/day), *A. esculentus* (7.6 E-04 mg/kg/day) from Omoku community, *A. esculentus* (7.6 E-04 mg/kg/day) from Okposi community and *A. esculentus* (3.8 E-04 mg/kg/day) from Elleta community were within the range of permissible predicted lifetime risks for carcinogens as suggested by USEPA [31]. This also is an indication that there may be risk of developing any type of cancer due to carcinogenic ingestion and exposure to Cd over time from these analyzed vegetables samples.

The LCR of Ni and As all exceeded the range of permissible predicted lifetime risks for carcinogens which indicates that there may not be risk of developing any type of cancer due to carcinogenic ingestion and exposure to Ni and As over time due to carcinogenic ingestion and exposure to Ni and As overtime.

4.6 Life Cancer Risk (LCR) for Children Population

The Life Cancer Risk (LCR) result in children population shown in table 7, shows that the LCR of Pb which ranged from (8.5 E-06 to 1.02 E-04 mg/kg/day) were all within the range of permissible predicted lifetime risks for carcinogens as suggested by USEPA [31]. This finding indicates that there may be risk of developing any type of cancer due to carcinogenic ingestion and exposure to Pb over time.

The LCR of Cd, Ni, and As all exceeded the range of permissible predicted lifetime risks for carcinogens which indicates that there may not be risk of developing any type of cancer due to carcinogenic ingestion and exposure to Cd, Ni, and As over time due to carcinogenic ingestion and exposure to Cd, Ni, and As overtime.

5. CONCLUSION

This study has highlighted the concentrations of the heavy metals of interest in selected vegetable samples. Data from this study has shown that the concentrations of heavy metals in edible vegetables under study were high. Results from this study also showed that only as and Fe in all the analyzed samples recorded THQ values less than 1. This is however an indication that the exposed population may not be at risk of As and Fe contamination and toxicity. On the other hand, THQ values of other metals namely (Pb, Cd, Ni, and Cu) in all the analyzed samples were all greater than 1, indicating that the exposed population in the study area may be at risk of Pb, Cd, Ni, and Cu contamination and toxicity due to the frequent consumption of these edible vegetables. It is therefore concluded that vegetables grown in the study areas (Obrikom, Omoku, Okposi, and Elleta community) may not be safe for consumption. The high levels of metals recorded in samples under study may be attributed to the frequent oil spillage from oil exploration carried out by the oil companies in this study area, pipelines vandalization, agricultural runoffs and industrial wastes, which tend to increase the accumulation of these heavy metals in the soil which are in turn absorbed by these plant roots. This could result to bio-accumulation of metals under study in the edible vegetables. This may in turn become a health risk concern to the populace of the study area when these edible vegetables enter the body system when they are consumed.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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