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Evaluation of Heavy Metals Content and Human Health Risk Assessment via Consumption of Vegetables from Selected Markets in Bayelsa State, Nigeria

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Abstract

The aim of this study was to evaluate the concentration of heavy metals namely (Lead (Pb), Nickel (Ni), Cadmium (Cd) and Chromium (Cr)) via consumption of vegetables from selected markets in Bayelsa State, Nigeria. Sixteen different vegetable samples comprising of Bitter leaves (*Vernonia amygdalina*), Curry leaves (*Ocimum basilicum*), Scent leaves (*Ocimum gratissmum*), Water Leaves (*Talinum triangulare*), Uziza (*Piper guineese*), Fluted pumpkin (*Telferia occidetalis*), Okazi (*Gnetum africanum*), and Okra (*Abelmoschus esculentus*) were digested and analyzed for heavy metals using Solar Thermo Elemental Flame Atomic Absorption Spectrophotometer (STEF-AAS). Results obtained were used to estimate the health risk of these heavy metals via consumption of the vegetable samples. The results from the study showed that the heavy metal concentration ranged between 0.016 to 1.387 mg/kg, 0.028 to 1.487 mg/kg, 0.093 to 3.625 mg/kg and 0.893 to 2.478 mg/kg for Pb, Cd, Ni and Cr respectively. The concentration of Pb was below permissible limit recommended by WHO/FAO. The concentration of Cd in *O. gratissimum* and *T. triangulare* from both markets exceeded the permissible limit recommended by WHO/FAO and EC/CODEX. The concentration of Ni in *O. gratissimum* and *T. occidetalis* from Kpanshia market exceeded the permissible limit recommended by NAFDAC while Cr from both markets exceeded permissible limit recommended by European community/CODEX. The Hazard Index (HI) values for all the samples under study were greater than (>) 1 which indicates that there is potential health risk to those consuming these vegetables except *A. esculentus* in Kpanshia market for adults which was less than (<) 1. The Target Hazard Quotient (THQ) concentrations of Pb in *O. gratissimum*, *T. occidetalis* and *G. africanum* from Kpanshia market and O. basilicum from Swali market, Cd in *T. triangulare* and *O. gratissimum* from both markets and Ni in *T. occidetalis* from Swali market for children only were all greater than 1 which indicates level of concern that the population may be at risk of either Pb, Ni or Cd toxicity. The Estimated Daily Intake (EDI) concentrations of Pb in *O. gratissimum*, *T. occidetalis* and *G. africanum* all from Kpanshia market, Cd in *T. triangulare* from both markets, and Ni in all the samples from both markets were all above the permissible tolerable daily intake (PTDI) limit as recommended by EFSA (European Food and Safety Agency) meaning that those who consume this product may be at risk. The results from the present study tends to suggest that consumption of vegetables from both markets under study in Bayelsa state could be one of the contributory factors to the heavy metal burden among consumers due to their frequent consumption.

Keywords: Air pollution; Sewage sludge; Chemical properties; Organic matter; Bioavailability

Introduction

Vegetables constitute an important part of the human diet since they contain carbohydrates, proteins, vitamins, minerals as well as trace elements. The contamination of vegetables with heavy metals due to soil and atmospheric contamination poses a threat to its quality and safety. Dietary intake of heavy metals also poses risk to animals and human health. High concentrations of heavy metals (Cu, Cd and Pb) in fruits and vegetables were related to high prevalence of upper gastrointestinal cancer. Many anthropogenic sources such as waste incineration, industrial processes and most importantly, vehicular traffic emit heavy metals into the atmosphere. Regulations have been set up in many countries and for different industrial set up to control the emission of heavy metals.

The uptake and bioaccumulation of heavy metals in vegetables are influenced by many factors such as climate, atmosphere depositions, the concentrations of heavy metals in soil, the nature of soil and the degree of maturity of the plants at harvest [1,2]. **Air pollution** may pose a threat to post-harvest vegetables during transportation and marketing causing elevated levels of heavy metals in vegetables. Elevated levels of heavy metals in vegetables are reported which such as long term uses of treated or untreated waste water. Other anthropogenic sources of heavy metals include the addition of manures, **sewage sludge**, fertilizers and pesticides which may affect the update of heavy metals by modifying the physico-**chemical properties** of the soil such as pH, **organic matter, bioavailability** of heavy metals in the soil [3]. Whatmuff and McBride [4,5] found that increasing concentrations of heavy metals in soil increased the crop uptake. Cultivation areas near highways are also exposed to atmospheric pollution in the form of metal containing aerosols. These aerosols can be deposited on soil and absorbed by vegetables, or alternatively deposited on leaves and fruits and then absorbed. High accumulation of Pb, Cr and Cd in leafy vegetables due to atmospheric depositions has been reported by Voutsa et al. and De Nicola et al. [2,6]. The levels of heavy metals (Zn, Mn, Cu and Pb) in vegetable (Talinum triangulare) collected from selected markets of bayelsa, Nigeria were found to be high. The partitioning of heavy metals is well known, with accumulation of greater concentrations in the edible portions of leafy or root crops than the storage organs or fruits [7-9].

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Urban activities may significantly contribute to elevated heavy metal loads in atmospheric deposits and consequently in the edible portion of the vegetables. Thus, the present study was conducted with the objectives to investigate the accumulation of heavy metals (Cu, Zn, Pb) on the vegetables. Water-washing by shaking mechanically removes much of the particulate found on the leaf surfaces, allowing the fractions of particle-bound heavy metals to be estimated. This study therefore, aimed to distinguish the water-removable fraction of heavy metals and the fraction present in leaves, potentially supplying useful information on the pollutant fraction damaging to leaf physiological processes. Heavy metals enter the body system through food, air, water and bio-accumulate over a period of time. Excess heavy metal accumulation in the environment is capable to have toxicological implications in human. Heavy metal pollution is of significant ecological/environmental concern this is due to the fact that they are not easily biodegradable or metabolized, thus precipitating far reaching effects on the biological system.

The aim of this study is to analyze the selected vegetables for the level of heavy metals. Also carry out health impact assessment at the various locations in order to suggest necessary measure that can alleviate the effects of such environmental contamination.

Materials and Methods

The present study was carried out in Bayelsa state located in the South-South region Nigeria. The climate of the region is tropical with two distinct seasons i.e., dry and rainy. The dry season (November to April) is associated with high temperature during the day ranging from a minimum of 30°C to a maximum of 36°C. Rainy season starts in May and continue till end of October. During the rainy season, the temperature varies from a minimum of 24°C to a maximum of 32°C.

Bayelsa is one of the riverine cities of Nigeria. There are several retailed markets in Bayelsa.

Vegetable markets

Two multipurpose retail markets were sampled. The magnitude of urban activities such as industrial, commercial buying and selling, varied between the sampling locate.

Leafy vegetables

Sixteen different vegetable samples comprising of Bitter leaves (*Vernonia amygdalina*), Curry leaves (*Ocimum basilicum*), Scent leaves (*Ocimum gratissmum*), Water Leaves (*Talinum triangulare*), Uziza (*Piper guineese*), Fluted pumpkin (*Telferia occidetalis*), Okazi (*Gnetum africanum*), and Okra (*Abelmoschus esculentus*) each were collected from Kpanshia and Swali markets in Bayelsa state, Nigeria.

Pretreatment and washing of samples

After collection, samples were brought to the laboratory and processed further for analysis. Edible portions of the samples were used while bruised or rotten portions were removed. The edible portions of the collected vegetable samples were properly washed to eliminate adsorbed dust particles. The vegetables were air-dried for twelve (12) days under hygienic condition to prevent further contamination from *in-situ* environment.

Digestion

A total volume of 100 ml of H_2SO_4, HNO_3, and $HClO_4$ in the ratio of 40%:40%:20% was mixed together. A portion (5 g) of the samples was weighed and digested with a 2 ml of the mixed acid to each of the samples in a kjedahl flask. The samples were then digested in a fume cupboard with hot plate until white fumes appeared. After that, the solution was then cooled, filtered and transferred into a 100-ml volumetric flask and made up to mark with distilled water.

Heavy metal health risk assessment

To assess the health risks associated with the ingestion of heavy metals from vegetables, the Estimated Daily Intake (EDI) of heavy metals, Target Hazard Quotient (THQ), Hazard Index (HI) and Total Carcinogenic Risk (CR) were calculated.

Estimated Daily Intake (EDI)

$$EDI = \frac{Cmetal \times Dfoodintake}{BWavergae}$$

Where:

C_{metal} is the metal concentration in vegetable in mg/kg,

$D_{food\ intake}$ is the daily intake of food in kg $person^{-1}$ and

$BW_{average}$ is average body weight in kg $person^{-1.}$

An average daily consumption of 0.2 kg of vegetable was assumed in this study. This value was adopted because vegetable constitute a major part of the diet. Average adult body weight was considered to be 60 kg.

Non-carcinogenic health effect

Target hazard quotient: Non-carcinogenic risk estimation of heavy metals consumption was determined using THQ values. THQ is a ratio of the determined dose of a toxicant to a reference dose considered harmful. 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 [10].

$$THQ = \frac{Efr \times ED \times FIR \times C}{RfDo \times Baverageweight \times ATn \times 10^{-3}}$$

Where

Efr is exposure frequency in 156 days $year^{-1}$,

ED is exposure duration in 56 years equivalent to an average lifetime,

FIR is average daily consumption in Kg $person^{-1}day^{-1}$,

C is concentration of metal in food sample in mg/kg

Rf Do is reference dose in mg/Kg day^{-1} and

ATn is average exposure time for non–carcinogens in days (156 × 56).

The following reference doses were used (Cd=0.001 mg/kg, Ni=0.02 mg/kg, Cr=1.5 mg/kg, Pb=0.0035 mg/kg) [11,12].

Calculation of hazard index: Hazard index 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) [13-16]. Since different pollutants can cause similar adverse health effects, it is often appropriate to combine HQs associated with different substances [17-21].

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

Carcinogenic health effect

Incremental lifetime cancer risk 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 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 as described by ATSDR in 2010 and it is contaminant specific [22-30]. 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 $(mg/kg/day)^{-1}$ (Cd=0.38, Pb=0.0085)

US EPA, 2011 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.

Results

Concentration (mg/kg) of heavy metals in selected vegetables

The results of different vegetable samples analyzed for lead, cadmium, nickel, and chromium are shown in Table 1. The results from the study showed that the concentration of Pb ranged between 0.016 to 1.387 mg/kg with the highest level recorded in *G. africanum* (1.387 mg/kg) followed by *O. gratissimum* (1.358 mg/kg) and *T. occidetalis* (1.163 mg/kg) all in Kpanshia market while the lowest level Pb was recorded in *A. esculentus* from Swali market (0.016 mg/kg). Cadmium concentration ranged from 0.028 to 1.487 mg/kg with the highest seen in *T. triangulare* (1.487) from Kpanshia market [31-36]. However, *V. amygdalina* from both markets and *O. basilicum* from Kpanshia market were below detectable limit (BDL<0.001). Nickel concentration ranged from 0.093 to 3.625 mg/kg. The highest concentration of Ni was observed in *O. gratissimum* (3.625 mg/kg) from Kpanshia market while the lowest level was recorded in *O. gratissimum* (0.093) in Swali market [37-43]. Cr concentration in the samples ranged from 0.893 to 2.478 mg/kg with the highest concentration recorded in *T. triangulare* (2.478 mg/kg) while the lowest level was recorded in *G. africanum* (0.893 mg/kg) both from Kpanshia market.

Estimated daily intake of metals for adults (mg/kg)

The results of the EDI for adults are shown in Table 2. The result of Pb was within the range of 0.001 to 0.007 mg/kg. However, *A. esculentus* from both Kpanshia and Swali markets, *T. occidetalis* and *G. africanum* in Swali market, Pb was found to be below detectable limit (4E-04, 8E-05, 8E-04 and 8E-04 mg/kg respectively) [44-49].

Cadmium ranged between 0.002 to 0.007 mg/kg with the highest concentration recorded in *T. triangulare* (0.007 mg/kg) from Kpanshia market. However, concentration of *V. amygdalina*, *O. basilicum* from Kpanshia market and *V. amygdalina* from Swali market were below detectable limits. The result of Ni was within the range of 0.002 to 0.018 mg/kg with *O. gratissimum* from Kpanshia market recording the highest value (0.018 mg/kg) while *O. gratissimum* from Swali market was below detectable limit [50-60].

Chromium value ranged between 0.004 to 0.012 mg/kg. The highest concentration was observed in *T. triangulare* (0.012 mg/kg) from Swali market.

Estimated daily intake of metals for children (mg/kg)

The results of the EDI for children are shown in Table 3. The concentration of Pb ranged between 0.001 to 0.012 mg/kg. Calculated EDI for Pb in children was highest in *O. gratissimum* (0.012 mg/kg) from Kpanshia market. Cadmium ranged from 0.001 to 0.013 mg/kg with *T. triangulare* recording the highest value (0.013 mg/kg). Calculated EDI for Ni ranged between 0.004 to 0.032 mg/kg with the highest value recorded in *O. gratissimum* (0.032 mg/kg) from Kpanshia market. The EDI for Cr in children ranged between 0.008 to 0.022 mg/kg with the highest value recorded in *T. triangulare* (0.022 mg/kg) from Kpanshia market (Tables 1-3). The non-carcinogenic risk of four heavy metals exposure to consumption of *L. flammea* from Bayelsa State are presented in Table 4.

Target hazard quotient and hazard index of heavy metals for adults

The THQ value greater than (>) 1 indicates health concern.

The non-carcinogenic risk of four heavy metals exposure to consumption of vegetables from Kpanshia and Swali markets in Bayelsa state are presented in Table 5. The THQ for Pb ranged from of

Location	Sample	Pb	Cd	Ni	Cr
Kpanshia Market	*V. amygdalina*	0.247	BDL	1.182	1.652
	O. basilicum	0.538	BDL	0.873	1.059
	P. guineense	0.315	0.036	1.354	1.786
	O. gratissimum	1.358	1.204	3.625	1.369
	T. triangulare	0.479	1.487	1.576	2.478
	T. occidetalis	1.163	0.155	2.815	1.683
	G. africanum	1.387	0.091	1.052	0.893
	A. esculentus	0.074	0.028	0.483	1.027
	V. amygdalina	0.279	BDL	1.782	1.049
	O. basilicum	0.716	0.093	0.964	1.308
	P. guineense	0.27	0.184	1.604	1.537
Swali Market	*O. gratissimum*	0.439	0.439	0.093	1.35
	T. triangulare	0.396	1.268	1.525	1.725
	T. occidetalis	0.168	0.158	2.39	0.958
	G. africanum	0.153	0.102	1.258	1.063
	A. esculentus	0.016	0.042	0.848	1.343

BDL<0.001; BDL: Below Detectable Limit

Table 1: Concentration of heavy metals in mg/kg in selected vegetable samples.

Location	Sample	Pb	Cd	Ni	Cr
Kpanshia Market	*V. amygdalina*	0.001	0	0.006	0.008
	O. basilicum	0.003	0	0.004	0.005
	P. guineense	0.002	2.00E-04	0.007	0.009
	O. gratissimum	0.007	0.006	0.018	0.007
	T. triangulare	0.002	0.007	0.008	0.012
	T. occidetalis	0.006	8.00E-04	0.014	0.008
	G. africanum	0.007	5.00E-04	0.005	0.004
	A. esculentus	4.00E-04	1.00E-04	0.002	0.005
	V. amygdalina	0.001	0	0.009	0.005
	O. basilicum	0.004	5.00E-04	0.005	0.007
	P. guineense	0.001	9.00E-04	0.008	0.008
Swali Market	*O. gratissimum*	0.002	0.002	5.00E-04	0.007
	T. triangulare	0.002	0.006	0.008	0.009
	T. occidetalis	8.00E-04	8.00E-04	0.012	0.005
	G. africanum	8.00E-04	5.00E-04	0.006	0.005
	A. esculentus	8.00E-05	2.00E-04	0.004	0.007

Table 2: Estimated Daily Intake (EDI) of heavy metals in mg/kg for adults (70 kg) from consumption of vegetables.

Location	Sample	Pb	Cd	Ni	Cr
Kpanshia Market	*V. amygdalina*	0.002	0	0.01	0.015
	O. basilicum	0.005	0	0.008	0.009
	P. guineense	0.003	3.00E-04	0.012	0.016
	O. gratissimum	0.012	0.011	0.032	0.012
	T. triangulare	0.004	0.013	0.014	0.022
	T. occidetalis	0.01	0.001	0.025	0.015
	G. africanum	0.012	8.00E-04	0.009	0.008
	A. esculentus	7.00E-04	2.00E-04	0.004	0.009
	V. amygdalina	0.002	0	0.016	0.009
	O. basilicum	0.006	8.00E-04	0.008	0.012
	P. guineense	0.002	0.002	0.014	0.014
Swali Market	*O. gratissimum*	0.004	0.004	8.00E-04	0.012
	T. triangulare	0.003	0.011	0.013	0.015
	T. occidetalis	0.001	0.001	0.021	0.008
	G. africanum	0.001	9.00E-04	0.011	0.009
	A. esculentus	1.00E-04	4.00E-04	0.007	0.012

Table 3: Estimated Daily Intake (EDI) of heavy metals (mg/kg) for children (24 kg) from consumption of vegetables.

Location	Samples	Pb	Cd	Ni	Cr	HI
Kpanshia Market	*V. amygdalina*	0.353	0	0.296	0.006	0.654
	O. basilicum	0.769	0	0.218	0.004	0.99
	P. guineense	0.45	0.18	0.339	0.006	0.974
	O. gratissimum	1.94	6.02	0.906	0.005	8.871
	T. triangulare	0.684	7.435	0.394	0.008	8.522
	T. occidetalis	1.661	0.775	0.704	0.006	3.146
	G. africanum	1.981	0.455	0.263	0.003	2.702
	A. esculentus	0.106	0.14	0.121	0.003	0.37
	V. amygdalina	0.399	0	0.446	0.003	0.848
	O. basilicum	1.023	0.465	0.241	0.004	1.733
	P. guineense	0.386	0.92	0.401	0.005	1.712
	O. gratissimum	0.627	2.195	0.023	0.004	2.85
Swali Market	*T. triangulare*	0.566	6.34	0.381	0.006	7.293
	T. occidetalis	0.24	0.79	0.598	0.003	1.631
	G. africanum	0.219	0.51	0.315	0.004	1.047
	A. esculentus	0.023	0.21	0.212	0.004	0.449

Table 4: Target hazard quotient (THQ) and Hazard index (HI) for adult exposed to vegetables contaminated with heavy metals.

Location	Samples	Pb	Cd	Ni	Cr	HI
Kpanshia market	*V. amygdalina*	0.621	0	0.52	0.01	1.151
	O. basilicum	1.353	0	0.384	0.006	1.743
	P. guineense	0.792	0.317	0.596	0.01	1.715
	O. gratissimum	3.414	10.6	1.595	0.008	15.61
	T. triangulare	1.204	13.09	0.693	0.015	15
	T. occidetalis	2.924	1.364	1.239	0.01	5.537
	G. africanum	3.487	0.801	0.463	0.005	4.756
	A. esculentus	0.186	0.246	0.213	0.006	0.651
	V. amygdalina	0.701	0	0.784	0.006	1.492
	O. basilicum	1.8	0.818	0.424	0.008	3.05
	P. guineense	0.679	1.619	0.706	0.009	3.013
Swali Market	*O. gratissimum*	1.104	3.863	0.041	0.008	5.016
	T. triangulare	0.996	11.16	0.671	0.01	12.84
	T. occidetalis	0.422	1.39	1.052	0.006	2.87
	G. africanum	0.385	0.898	0.554	0.006	1.842
	A. esculentus	0.04	0.37	0.373	0.008	0.791

Table 5: Target hazard quotient (THQ) and Hazard index (HI) for children exposed to vegetables contaminated with heavy metals.

0.023 to 1.981 mg/kg with the highest value recorded in *G. africanum* (1.981 mg/kg) in adult whereas calculated THQ values in children ranged between 0.040 to 3.487 mg/kg with *G. africanum* (3.487 mg/kg) recording the highest.

THQ value of Cd ranged between 0.180 to 7.435 mg/kg and 0.317-13.09 mg/kg for adult and children respectively. However, *T. triangulare* from Kpanshia market recorded the highest THQ values of 7.435 and 13.09 mg/kg for both adult and children respectively [61-65].

The THQ value for Ni ranged between 0.023 to 0.906 mg/kg and 0.041 to 1.595 mg/kg for adult and children respectively. However, the highest values adults and children were seen in *O. gatissimum* (0.906 mg/kg and 1.595 mg/kg) from Swali and Kpanshia markets respectively.

The THQ value of Cr was within the range 0.003 to 0.008 mg/kg and 0.006 to 0.015 mg/kg for adult and children respectively. The highest value was recorded in *T. triangulare* (0.008 and 0.015 mg/kg) in both adult and children respectively from Kpanshia market.

On the other hand, the result of HI of adults and children from both Kpanshia and Swali market were in the range 0.370 to 8.871 mg/kg and 0.791 to 15.61 mg/kg respectively. The highest HI value in adult was recorded in *O. gratissimum* (8.871 mg/kg) whereas the highest HI value in children was recordedin *O. gratissimum* (15.61 mg/kg) from Swali market (Tables 4 and 5).

Discussion

The intake of food contaminated with chemicals may result to intoxication that can be described as acute or when the disease appears after a latent period of time and long term or chronic intoxications. 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. The present study has highlighted the contamination profile of vegetables commonly consumed from selected major markets in Bayelsa state, Nigeria and the possible public health implications.

Lead concentration in the samples under study from both Kpanshia and Swali markets was lower than the 2.0 mg/kg value as recommended by WHO/FAO. Among all samples analyzed for Pb, *O. basilicum*, *O. gratissimum*, *T. occidetalis* and *G. africanum* all from Kpanshia market were above 0.3 mg/kg as recommended by European communities (Commission of the European Communities, 2001). Lead is known to induce reduced cognitive development and intellectual performance in children and cardiovascular disease and increased blood pressure in adults (European Communities, 2001).

The concentration of Cadmium in the samples collected from both Kpanshia and Swali markets showed that Pb concentrations in *O. gratissimum* and *T. triangulare* from both Kpanshia and Swali markets exceeded the permissible limit of 1.0 mg/kg and 0.2 mg/kg as recommended by WHO/FAO and EC/CODEX respectively. Cadmium has been reported to accumulate in the human body and hence induce kidney dysfunction, skeletal damage and reproductive deficiencies (EC, 2001).

Nickel concentration in the samples from both Kpanshia and Swali markets showed that levels recorded in *O. gratissimum* and *T. occidetalis* exceeded the permissible limit of 2.7 mg/kg recommended by NAFDAC. Inhaled nickel 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. Nickel allergy can also cause systematic reactions.

The concentration of Cr in the samples collected from Kpanshia and Swali markets exceeded the European Community/CODEX standard of 0.3 mg/kg. Chromium (III) is an essential nutrient that helps the body use sugar, protein and fat but Chromium (VI) is carcinogenic (Institute of Medicine, 2002). Adverse health effects may arise from excessive amount of chromium (III) (Agency for Toxic Substances and Disease Registry, 2004). There is no upper tolerable intake level for chromium according to the Institute of Medicine but the AI of chromium for women and men 51 to 70 years old is 20 mg/day and 30 mg/day respectively. Deficiency of Cr results in impaired growth and disturbances in glucose, lipid and protein metabolism. However, Cr (IV) is carcinogenic [66-71].

Discussion

Risk assessment

Estimated daily intake of metals: The EDI is used to calculate the amount of metal taken by an adult or children per day. From the results for both adults and children, the concentrations of lead in *O. gratissimum*, *T. occidetalis* and *G. africanum* all from Kpanshia market, Cadmium in *T. triangulare* from both markets, and nickel in all the samples from both markets were all above the permissible tolerable daily intake (PTDI) limit as recommended by EFSA (European Food and Safety Agency) meaning that those who consume this products may be at risk while concentration on Chromium was below the PTDI thereby attracting no health risk.

Hazard index

The HI is the calculation which shows when a population is at risk. From the result in the present study for both adults and children, it was observed that the HI values for all the samples under study were greater than (>) 1 which indicates that there might be a potential health risk to those consuming these vegetables except for *A. esculentus* in Kpanshia market for adults which was less than (<) 1.

Target hazard quotient

The THQ value is a dimensionless index of risk associated with long term exposure to chemicals. From the result in the present study for both adults and children, the concentrations of Pb in O. gratissimum, *T. occidetalis* and *G. africanum* from Kpanshia market and O. basilicum from Swali market, Cd in *T. triangulare* and *O. gratissimum* from both markets and Ni in *T. occidetalis* from Swali market for children only were all greater than 1 which indicates level of concern that the population may be at risk of either Pb, Ni or Cd toxicity.

Conclusion

The results from the present study tends to suggest that consumption of vegetables from both markets under study in Bayelsa state could be one of the contributory factors to the heavy metal burden among consumers due to their frequent consumption.

Recommendation

It is therefore necessary to monitor extensively and occasionally heavy metals in vegetables especially those grown in areas where you have oil pipes which have been vandalized as a result of war or conflict by authorized government agencies in order to safeguard the health of the population.

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