HEAVY METALS CONCENTRATION IN GREENS SOLD IN UMUAHIA-MARKET NIGERIA: ASSESSMENT OF RISK TO HUMAN HEALTH

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Abstract

Background: The consumption of foods with a high concentration of heavy metals has increased the chances of incurring cancer and health disorders. In this study, the risks associated with ingestion and consumption of heavy metals in vegetables from Umuahia market was evaluated. Methods: Ten different vegetables were purchased from the Ubani market, in Umuahia – Nigeria. The vegetables - *Gnetum africanum*, *Vernonia amygdalina*, *Talinum triangulare*, *Solanum macrocarpon*, *Ocimum gratissimum*, *Gongronema latifolium*, *Pterocarpus mildbraedi*, *Telfairia occidentalis*, *Amaranthus hybridus*, and *Piper guineense*, respectively were randomly selected and used to screen for heavy metals. The vegetable samples were air dried, ground and digested with HNO_3, and $HClO_4$, acid, in a 5:1 ratio, separately using standard methods. The heavy metal contents of the acid digests were analyzed using Atomic absorption spectrophotometer. Results: The risk assessment of human health was interpolated with standard models. Results of the heavy metal showed that the vegetables have a high level of heavy metals. Some of the heavy metals detected in the vegetables exceeded their respective safety levels. The concentrations of zinc, nickel, and cobalt were not detected in most vegetables. Copper, chromium, and cadmium were above the permissible limits. Iron concentration was (12.092±0.100ppm) in *Amaranthus hybridus* which was the highest. The daily intake of heavy metals in vegetables was below tolerable prescription. The hazard index of the vegetable - *G. latifolium* was greater than 1, which implied adverse health effect. The hazard index - *A. africanum* and *T. triangulare* were equal to 1 suggesting that adverse health effect may occur. *P. schum* had a high concentration of chromium which makes it unsafe for consumption due to the risk of cancer. Lead showed no cancer risk, while nickel, chromium, and cadmium in vegetables were within the acceptable risk ($<10^{-6}$). The total cancer risks of all vegetables were less than ($<10^{-6}$) suggesting no/low chance of developing cancer. Conclusion: The consumption of these vegetables with heavy metals over a long period of time may put the consumers at risk. This study recommend that some vegetables used for this investigation are unsafe for human consumption. The decisión to inform the consumers about the possible health

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effects of consuming/ingesting heavy metals in order to prevent metal toxicity is strongly advise.

Keywords: *vegetables, risk-assessment, hazard-index, heavy metals, public health*

Introduction

Empirically, one can define heavy metals as metals with a density greater than 5 mg mL-1.The identification of heavy metals comprises of - arsenic, cadmium, chromium, copper, lead, nickel, molybdenum, vanadium, iron and zinc. Some metals are known for their micronutrients, including - zinc, copper, nickel, chromium, and iron with influence at physiological functions (Joan *et al.*, 2017). The cultivation of crops by farmers has taken different forms, most farmers indulged in unethical practices during farming. Most farmers irrigate their farmland with wastewater, while others resort to planting their crops on dumpsite, with the intention of utilizing composed manure. This act may lead to a continuous buildup of metals which are translocated into the vegetable and become accumulated. It should be noted that crops irrigated with wastewater or planted in waste dump sites are hazardous. It was found that vegetables growing within or around wastewater arena are not safe for human consumption (Sharma et al., 2016). The art of composting is a very cheap practice and reasonable techniques for waste containing organic matter. If the compost contains a high concentration of heavy metals amounting to a toxic level, one may consider them harmful to human and environment. Heavy metals are toxic to the soil ecosystem, plants, aquatic organisms, and human health if their concentration is high enough in the soil that was used to cultivate the vegetables. They may elicit toxic effects on the soil biota by impeding the microbial processes and decreasing the activity of soil microorganisms. At trace level, some heavy metals may inhibit the metabolism of some plant (Singh and Kalamdhad, 2011). The uptake of heavy metals by plants and progressive partitioning along the food chain is a potential risk to the animals and human health.

Heavy metals such as As, Cd, Hg, Pb, and Se may not be needed for plants growth since they do not play major physiological function in plant's anatomy. Others heavy metals such as Co, Cu, Fe, Mn, Mo, Ni, and Zn are requisite elements needed for normal growth, development, and metabolism in plants. Although these elements can easily cause poisoning when their concentrations are greater than the safety values (Garrido *et al.*, 2002; Rascio and Izzo, 2011, cited in Singh and Kalamdhad (2011). The use of compost manure may improve the yield of vegetables, though when the soil quality and irrigation wáter is not analysed to acertain the haeavy metal level, partitioning of metals in the soil and bioaccumulation in plants will occur. Heavy metals readily compete with the essential elements as a result of their chemical resemblance and interaction with divalent/monovalent transporters, which affect various physiological functions (Inbaraj and Chen, 2012). Heavy metals exert toxic effects on various biological systems including cardiovascular, neural, hematopoietic, immunological, and kidney (Inbaraj and Chen 2012; Zafarzadeh and Mehdinejad, 2015). Some of the heavy metals such as manganese (Mn), cobalt (Co), molybdenum (Mo), Cu, and Zinc promote the growth of animals and human when present in moderate quantity, while other metals such as Cadmium, Arsenic, and Chromium act as carcinogens (Ali et al., 2018). Also, Hg and Pb has been implicated in the causation of teratogenicity in newborn babies (Trichopoulos *et al.*, 1986 cited by *Ali et al.*, 2018). (Hartwig, 1998, cited in Ali *et al.*, 2018) reported that the ingestion of Cd over a long period of time may cause renal, prostate, and ovarian cáncer in humans. Vegetables are good sources of vitamins, minerals, and fibers and pose antioxidant effects on free radicals. Vegetable constituents are important parts of the human diet. They retain carbohydrates, proteins, vitamins, and trace elements (Abdulla and Chmielnicka, 1989 cited in Ali et al., 2018). Therefore, regular intake of vegetables that are contaminated with heavy metal may pose a health risk to the consumers. Vegetables take up heavy metals and accumulate them in their edible portions (Arora et al., 2008). Consuming these metal-rich plants and their edible portions may result in adverse health outcomes in animals and humans (Alam et al., 2003). These metal have the propensity to deregulate immunological defenses, retardation of intrauterine growth, impairment of psychosocial behavior, and elevated risk of upper part of gastrointestinal cancer (Alam et al., 2003; Arora et al., 2008). Carcinogenic effects due to the frequent consumption of fruits and vegetable burden with heavy metal have been established. There is generous information on the detrimental health risk of ingesting heavy metal. In order to create a platform for advocacy and awareness on the need for quality vegetable, its why this work was designed to evaluate human health risk assessment of heavy metals by analyzing selected edible and vegetables sold in the Ubani market in Umuahia, Nigeria.

Materials and Methods

Collection and Description of Vegetable Crops

Ten different vegetables that are customarily consume are sold at the Ubani market in Umuahia, Abia State. They were selected and purched for research. They include *Gnetum africanum* (*Eru* or Wild spinach), it is a vine gymnosperm species found in tropical Africa. *Gnetum africanum* is a wild vine, consider as a wild vegetable. Primarily, *Eru* leaves are used for cooking vegetable soups and stews. They are commonly called *Eru soup* or *afang soup* (Benson and Ebong, 2005) see Figure 1 a. Better leaf (*Vernonia amygdalina)* belongs to the daisy family, it is a shrub that grows in Africa. V. amygdalina is used for treatment and management of humans and animals diseases in Africa see Figure 1b. Waterleaf (*Talinum triangulare*) is a non-conventional vegetable crop which originats from Africa. Nutritionally,

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waterleaf has high crude-protein (22.1%), ash (33.98%), and crude fiber (11.12%). It exerts some medicinal values in humans and acts as green forage for rabbit Figure 1c. Eggplant *(Solanum macrocarpon)* otherwise known as the African eggplant or gboma, belong to the Solanaceae family. *S. macrocarpon* is a perennial plant that is related to eggplant (Osma et al., 2012). *S. macrocarpon* originates from West Africa, and distributed to Central and East Africa Figure 1d.

a) Wild spinach (ulcazi)
(*Gnetum africanum*)

b) Bitter leaf
(*Vernonia amygdalina*)

c) Water leag
(*Talinum triangulare*)

d) Eggplant leaf
(*Solanion macrocarpon*)

e) African basil – Scent leaf
(*Ocimum gratissimum*)

f) Bush buch (utazi)
(*Gongronema latifolium*)

g) Oha
(Pterocarpus mildbraedi)

h) Fluted pumpkin leaf (Ugu)
(*Telfaira occidentalis hook f.*)

i) African spinach
(*Amaranthus hybridus*)

j) False cubeb
(*Piper guineense*)

Figure 1.
The selected vegetables

Ocimum gratissimum, also known as clove basil, African basil, and in Hawaii is a wild basil, it is a species of *Ocimum*. The essential oil of *Ocimum gratissimum* contains eugenol and shows evidence of antibacterial activity (Khanna and Khanna (2011). A polyherbal preparation of water extract of *Gongronema latifolia*, *Vernonia amygdalina*, and *Ocimum gratissimum* showed analgesic and antidiabetes activity (Idodo-Umeh and Ogbeibu, 2010; Uboh et al., 2011) see Figure 1 e. *Gongronema latifolium* (Benth) (Asclepiadaceae), is a climber with wood hollow glabrous stem, it is characterized by greenish-yellow flowers. The Efik/Ibibio people in Southern Nigeria call the leaves 'Utasi', the Igbos call it 'utazi' and the Yoruba people 'arokeke' or 'Maduro' find Figure 1f. *Pterocarpus mildbraedii* is an evergreen or semi-deciduous tree with a small, rounded crown; it can grow 15 - 25 meters tall. The edible leaves are usually harvested for domestic and commercial purpose, Figure 1g. Fluted Pumpkin (*Telfairia occidentalis hook f.*) is a species of Cucurbitaceae, which grows in the tropics and largely consumed in Nigeria, Ghana, and Sierra Leone. The common names include Ubong in the Ibibio language in Nigeria and Ugu in the Igbo language. It is a creeping vegetable that spreads low on the ground with lobed leaves and long twisting tendrils see Figure 1 h. *Amaranthus hybridus* -African spinach (green) is an annual herbaceous plant with about 1- 6 feet tall. The leaves are alternate petioled, 3 – 6 inches length, dull green, and rough, hairy, ovate or rhombic with wavy margins. It is a common species whose growth is aboundand in waste dumpsite (Mepha et al., 2007) see Figure 1i. *Piper guineense* - False cubeb leaves *(uziza) Piper guineense* is a West African specie of *Piper*; the spice is gotten from dried fruit called Ashanti pepper. In terms of flavor, Ashanti pepper is similar to cubeb pepper, but is less bitter and has a fresher, herbaceous flavor and aroma than cubebs (Khadeeja et al., 2013) see Figure 1 j.

Preparation of vegetables

The vegetables were washed thoroughly with tap water followed by distilled water to remove adsorbed substances. Samples were sliced into small pieces, air dried for 48 hrs and kept in a hot air oven at 100°C ± 1°C for unrecorded hours. Dried samples were pulverized to a fine powder and passed through a 1 mm mesh. Each vegetable was labeled (A_1 – A_{10}), respectively. They were stored in a dry plastic container that was previously cleaned with concentrated nitric acid to prevent heavy metal contamination prior to analysis. The heavy metals were screened with atomic absorption spectrophotometer (AAS).

Digestion and determination of vegetable and fruit samples

To each vegetable sample, 0.5 g of the dried sample was digested with HNO_3, and $HClO_4$, in a 5:1 ratio until a transparent solution was obtained (Adah et al., 2013). The fruit and vegetable digests were filtered and diluted with distilled water to 25 ml. The heavy metal in the acid digests of the samples were then analysed for heavy metal concentration.

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Determination of heavy metal concentration in vegetable and fruit samples

The heavy metals were determined using Atomic Absorption Spectrophotometer, (Thermo Scientific Pvt. Ltd. India Model No. AA 303). Double Beam and deuterium background hollow cathode lamps of Fe, Pb, Cd, Zn, Cu were used at specific wavelengths. All samples were run in triplicates.

Determination of daily intake of heavy metals (DIM)

The daily intakes of heavy metals (DIM) were determined using the method of (Anwange *et al.*, 2013). The daily intake of metals was calculated using equation 1.

$$DIM = \frac{C_{\text{metal}} \times D_{\text{vegetable/fruit intake}}}{Bw_{\text{average}}} \quad [1]$$

Where:
C_{metal} is the metal concentration in vegetable in mg/kg,
$D_{\text{vegetables/fruits}}$ intake is the daily intake of fruit/vegetable (300g/kg/day)
$B_{W\ \text{average}}$ is the average body weight of a Nigerian (62 kg)

Determination of non-carcinogenic risk index

The non-carcinogenic risk assessments are performed in order to estimate the potential health risks of pollutants using the target hazard quotient (THQ). The target hazard quotient values through the consumption of vegetables were assessed for each heavy metal and calculated using the standard assumption for an integrate USEPA risk analysis see equation 2.

$$THQ = \frac{DIM}{RfD} \quad [2]$$

where: DIM is the daily intake of metals (Mg/Kg/person)
RfD is the oral reference dose (mg kg^{-1} d^{-1})
RfDs are based on 0.04, 0.02, 0.03, 0.7, 0.003, 0.001, 0.014, 0.3 and 0.004 mg kg^{-1} d^{-1} for Cu, Ni, Co, Fe, Cr, Cd, Mn, Zn, and Pb, respectively (USEPA, 2010).
It should be noted that if the THQ value is less than 1, the exposed population is unlikely to experience adverse health hazard. Conversely, if the THQ is equal to or greater than 1 (≥ 1), there are chances that potential health risk may occur. Thus, interventions and protective approach could be taken (Wang et al., 2005).

Determination of hazardous index (HI)

In order to estimate the risk to human health with more than one heavy metal (HM), the hazard index (HI) developed (US EPA, 1989) was adopted. The hazard index is the sum of the hazard quotients for all HMs, calculated using equation 3 (Guerra et al., 2010).

$$\mathbf{HI = \sum THQ = THQ_{Cu} + THQ_{Ni} + THQ_{Co} + THQ_{Fe} + THQ_{Cr} + THQ_{Cd} + THQ_{Mn} + THQ_{Zn} + THQ_{Pb} \ldots} \quad [3]$$

where: HI = Hazard Index and THQ = Target Hazard quotient

Hazard Quotient (HQ) for the consumers of contaminated vegetables was assessed by the ratio of Daily Intake of Metal (DIM) to the oral reference dose (RfDo) for each metal. If the value of HQ is less than 1, then the exposed consumers are said to be safe if HQ is equal to or greater than 1, it is considered unsafe for human health. Thus potential health risk may occur.

Determination of carcinogenic risk index

Carcinogenic risk (CR) indicates an incremental chance of an individual to developing cancer over an extended life due to exposure to a potential carcinogen. The risk of incurring cancer by a consumer of heavy metals - Ni, Cr, Cd, and Pb contaminated vegetable was obtained using cancer slope factor (CSF), provided by (USEPA, 2000). See equation 4 used for the estimation of the cancer risk.

$$CR = CSF \times EDI \quad [4]$$

where, CSF is the oral carcinogenic slope factor of 0.0085, 0.38, 0.5, 1.7 $(mg/kg/day)^{-1}$ for Pb, Cd, Cr, and Ni respectively and 1.5 $(mg/kg/day)^{-1}$. EDI is the estimated daily intake of heavy metals. Acceptable risk levels for carcinogens range from 10^{-4} (risk of developing cancer over a human lifetime is 1 in 10000) to 10^{-6} (risk of developing cancer over a human lifetime is 1 in 1000000).

Determination of total carcinogenic risk

The cumulative cancer risk due to exposure to multiple carcinogenic heavy metals through the consumption of a particular type of vegetables was the sum of the individual heavy metal increment risk and calculated by using equation 5 (Li *et al.*, 2014).

$$\text{Total cancer risk} = \sum CR \quad [5]$$

where CR is the cancer risk

Statistical analysis

The data were subjected to One-way Analysis of Variance (ANOVA). Significant differences were accepted at $p < 0.05$. Results are expressed in means ± standard errors of means (SEM). The analysis was computed using Statistical Product and Service Solutions (SPSS) software version 22.

Results and discussion

Heavy metal (HM) contamination and their accumulation in vegetables have become a serious problem around the world caused by their toxicity, abundant sources, non-biodegradable properties, and accumulative behavior of HMs (Bifeng

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et al., 2017). Result in Table 1 shows the concentrations of heavy metals in vegetables sold at Ubani ‘market in Nigeria. Lead, zinc and cobalt concentration was below the detection limit in the vegetable exception of *G. africanum* whose lead concentration was - 0.01±0.00 ppm (above the permissible limit). Zinc concentration in *T. triangular* was (0.147±0.00 ppm), *O. gratissium* (0.097± 0.001 ppm), *G. latifolium* (0.144±0.001 ppm), *and P. mildbraedi* (0.031±0.001 ppm), respectively.

Table 1. *Concentrations of heavy metals in vegetables and their respective permissible limits*

Samples	Cu	Ni	Co	Cr	Fe	Cd	Mn	Zn	Pb
					(ppm)				
Limits of metals in vegetables	**0.010** ±0.000^{a}	**0.020** ±0.000^{c}	**2.000** ±0.000^{h}	**0.003** ±0.00^{a}	**5.00** ±0.000^{e}	**0.001** ±0.00^{bc}	**0.30** ±0.00^{bc}	**2.00** ±0.00^{e}	**0.01** ±0.00^{a}
G. africanum	**0.128** ±0.003^{e}	**0.103** ±0.002^{h}	**0.066** ±0.004^{g}	**0.042** ±0.00^{c}	**3.612** ±0.008^{b}	**0.013** ±0.002^{g}	**2.218** ±0.012^{g}	**ND**	**0.006** ±0.00^{b}
V. amygdalina	**0.099** ±0.002^{c}	**0.02** ±0.000^{c}	**0.056** ±0.002^{f}	**0.086** ±0.002^{e}	**3.135** ±0.030^{a}	**0.017** ±0.003^{ab}	**0.184** ±0.003^{ab}	**ND**	**ND**
T. triangulare	**0.116** ±0.002^{d}	**0.092** ±0.000^{g}	**ND**	**0.231** ±0.010^{j}	**4.638** ±0.200^{d}	**0.021** ±0.002^{f}	**1.61** ±0.01^{f}	**0.147** ±0.000^{d}	**ND**
S. macrocarpon	**0.135** ±0.001^{fg}	**0.079** ±0.002^{f}	**0.035** ±0.002^{d}	**0.069** ±0.000^{d}	**4.337** ±0.030^{c}	**0.023** ±0.001^{c}	**0.353** ±0.002^{c}	**ND**	**ND**
O. gratissimum	**0.149** ±0.004^{i}	**0.068** ±0.000^{e}	**0.020** ±0.000^{b}	**0.114** ±0.004^{f}	**3.092** ±0.009^{a}	**0.024** ±0.002^{bc}	**0.335** ±0.003^{bc}	**0.097** ±0.001^{b}	**ND**
G. latifolium	**0.138** ±0.004^{h}	**0.093** ±0.002^{g}	**0.046** ±0.003^{e}	**0.212** ±0.003^{i}	**4.442** ±0.110^{cd}	**0.025** ±0.002^{h}	**2.432** ±0.003^{h}	**0.144** ±0.001^{c}	**ND**
P. mildbraedi	**0.132** ±0.001^{ef}	**0.012** ±0.000^{a}	**0.007** ±0.000^{a}	**0.224** ±0.011^{j}	**3.082** ±0.020^{a}	**0.028** ±0.001^{abc}	**2.432** ±0.002^{abc}	**0.031** ±0.001^{a}	**ND**
T. occidentalis	**0.146** ±0.003^{i}	**ND**	**0.032** ±0.001^{c}	**0.015** ±0.00^{b}	**5.419** ±0.100^{f}	**0.029** ±0.002^{d}	**2.432** ±0.010^{d}	**ND**	**ND**
A. hybridus	**0.129** ±0.002^{e}	**0.037** ±0.001^{d}	**ND**	**0.194** ±0.002^{h}	**12.092** ±0.100^{g}	**0.026** ±0.002^{d}	**2.432** ±0.002^{d}	**ND**	**ND**
P. guineense	**0.063** ±0.002^{b}	**0.016** ±0.000^{b}	**ND**	**0.14±** 0.001^{g}	**3.699** ±0.300^{b}	**0.026** ±0.003^{e}	**2.432** ±0.010^{e}	**ND**	**ND**

Values are presented as mean ± standard deviation (n = 3) and values with different supper scripts in each of the columns are significantly ($P < 0.05$) different.

They were below the permissible limit. Cobalt concentration was not recorded in *T. triangulare, A. hybridus, and P. guineense*. Copper, Chromium, Iron, Cadmium and Manganese concentrations vary in different vegetables, as some were low, higher and others undetected. In the case of Manganese, its concentration in *V. amygdalina* was below the permissible limit (low). Iron concentration in *G. africanum, G. latifolium, P. muldbraedi* and *P. guineese*, respectively were below the permissible limit. Remarkably, was *A. hydridus* which have the highest iron concentration - 12.092±0.100 ppm, consider far above the recommended safety value (high). Copper and chromium were above the permissible limits 0.063±0.002 in *P. guineese,* 0.149±0.004 ppm in *O. gratissimum* and 0.015±0.00 in *T. occidentalis* and 0.224±0.011 ppm in *P. mildbraedi*, respectively. The concentration of Cadmium in the vegetable was above the permissible limit in *G. latifolium, P. mildraedi, T. occidentalis, A. hybridus and P. guineense* having similar values. The cadmium, chromium and copper concentration in the vegetable samples were above the permissible limits prescribed by FAO/WHO (2007).

Adewole and Uchegbu (2010), reported that leafy vegetables can readily accumulate Cd more efficiently than any other heavy metals in the soil. Chromium is a mineral in vegetables that plays a critical role in the metabolism of nutrients through the aid of insulin. Chromium picolinate is found in dietary supplements (Vincent, 2003).
Copper is also an essential micronutrient whose catalytic functions in humans are required for body pigmentation, maintain the health of the central nervous system and prevent anemia (Sobukola *et al.*, 2010). However slight increases in the levels of copper and chromium (beyond the permissible limits) may interfere with physiologic processes leading to the liver and kidney damage (Al Jassir *et al.*, 2005).
Result in Table 2 is the representation of the daily intake of heavy metals in vegetables that are sold in the Ubani market in Nigeria. Cadmium in all the vegetables were below the tolerable daily intake 4.0E-02, 7.0E-01, 15E-01 and 1.0E-03, respectively. As for lead, there was no daily intake, except for *A. africanum* **-** 2.8E-05, which was below the tolerable daily intake 4.0E-03. The daily intake of Zinc for the consumption of *T. triangulare. O. gratissimum, G.latifolium*, and *P. mildbraed* were indicated, while the daily intake of Zinc for *A.africanum*, *V. amygdalina*, *S. macrocarpon*, *T. occidentalis*, *A. hydridus*, and *P. guineense*, respectively wasn't indicated. Further observation shows that the daily intake of Nickel in *T. occidentalis* and Cobalt in *T. triangulare*, *A. hybridus*, *P. guineense* were not detected. The daily intake of manganese for *A. africanum* and *G. latifolum* vegetable were within the tolerable daily intake 1.4E-02. The value of lead in *G. africanum* was high, in line with (Sharma *et al.*, 2007) who found that leaves absorb great quantities of lead from the atmosphere.

Table 2. ***Daily intake of heavy metals in vegetables (mg/kg/day)***

Vegetables	Cu	Ni	Co	Fe	Cr	Cd	Mn	Zn	Pb
A. africanum	6.2E-04	5.0E-04	3.2E-04	1.8E-02	2.0E-04	6.3E-05	1.1E-02	-	2.8E-05
V. amygdalina	4.8E-04	9.7E-05	2.7E-04	1.5E-02	4.1E-04	8.2E-05	8.9E-04	-	-
T. triangulare	5.6E-04	4.5E-04	-	2.2E-02	1.1E-03	1.0E-04	7.8E-03	9.5E-04	-
S. macrocarpon	6.5E-04	3.8E-04	1.7E-04	2.1E-02	3.3E-04	1.1E-04	1.7E-03	-	-
O. gratissimum	7.2E-04	3.8E-04	9.7E-05	1.5E-02	5.5E-04	1.2E-04	1.6E-03	6.2E-04	-
G. latifolium	6.7E-04	4.5E-04	2.2E-04	2.2E-02	1.1E-03	1.2E-04	1.3E-02	9.3E-04	-
P. mildbraedi	6.4E-04	5.8E-05	3.4E-05	1.5E-02	1.1E-03	1.4E-04	1.1E-03	2.0E-04	-
T. occidentalis	7.1E-04	-	1.6E-04	2.6E-02	7.3E-05	1.4E-04	3.2E-03	-	-
A. hybridus	6.2E-04	1.8E-04	-	5.9E-02	9.4E-04	1.3E-04	6.4E-04	-;	-
P. guineense	3.0E-04	7.7E-05	-	1.8E-02	6.8E-04	1.3E-04	4.5E-03	-	-
RfD_o	4.0E-02	2.0E-02	4.3E-02	7.0E-01	15E-01	1.0E-03	1.4E-02	3.0E-01	4.0E-03

Values above the tolerable intake of each heavy metal give rise to negative health effect

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In humans, lead causes a wide range of biological effects depending on the level, frequency of exposure and duration of exposure. High lead intake may affect interior systems including nervous, renal, reproductive, and hematological and immune system (Dongre *et al.*, 2010). The target hazard quotient (HQ) of heavy metals of vegetables sold at the urban market is presented in Table 3.

Table 3. *Target hazard quotients (HQ) of heavy metals in vegetables*

Vegetables	Cu	Ni	Co	Fe	Cr	Cd	Mn	Zn	Pb
A. africanum	0.016	0.025	0.007	0.025	0.0001	0.063	0.767	-	0.007
V. amygdalina	0.02	0.005	0.006	0.022	0.0003	0.082	0.064	-	-
T. triangulare	0.014	0.022	-	0.032	0.0008	0.101	0.557	0.003	-
S. macrocarpon	0.016	0.019	0.004	0.030	0.0002	0.111	0.122	-	-
O. gratissimum	0.018	0.016	0.002	0.021	0.0004	0.116	0.116	0.002	-
G. latifolium	0.017	0.023	0.005	0.031	0.0007	0.121	0.958	0.003	-
P. mildbraedi	0.016	0.003	0.001	0.021	0.0007	0.135	0.080	0.001	-
T. occidentalis	0.018	-	0.004	0.037	0.0001	0.140	0.231	-	-
A. hybridus	0.016	0.009	-	0.084	0.0006	0.126	0.046	-	-
P. guineense	0.008	0.004	-	0.026	0.0005	0.126	0.319	-	-

An HQ < 1 indicates no adverse health effects, while HQ ≥ 1 indicates that adverse health effects are likely to occur. If HQ is equal to or greater than 1, it is considered unsafe for human consumption, therefore potential health risk may occur.

It was observed that all the respective heavy metals had their target hazard quotient below one. Interestingly, the target hazard quotient of lead was noticed in A. africanum only, zinc was observed in *T. trangulare, O. gratissinum, G. latifolum,* and *P. mildbraedi,* respectively. The target hazard quotient for copper, iron, chromium, cadmium, and manganese was indicated in all the vegetable samples analyzed. Nickel and Cobalt indicated their target hazard quotient in all the samples except *T. occidentalis* for Nickel and *T. triangulare, A. hybridus* and *P. guineense* for cobalt. Manganese - target hazard quotient approximately one, which was seen in *A. africanum* 0.767, *T. triangualre* 0.557 and *G. latifolium* 0.958, respectively. The hazard index of heavy metals of vegetables sold at the Ubani market can be found in Table 4.

Table 4.
Hazard index of heavy metals in vegetables

Vegetables	Hazard index
G.africanum	0.9101
V.amygdaline	0.1993
T.triangulare	0.7298
S. macrocarpon	0.3022
O. gratissimum	0.2896
G.latifolium	1.1587
P. mildbraedi	0.2577
T. occidentalis	0.4301
A.hydridus	0.2816
P.guineense	0.4835

An HI < 1 indicates no adverse health effects, while HI ≥1 indicates that adverse health effects are likely to occur.

The sample - *G. latifolium* have a hazard index greater than one (>1). The hazard index for the consumption of *V.amygdaline, S. macrocarpon, O. gratissimum, P. mildbraedi, T. occidentalis, A. hydridus,* and *P. guineense* was less than 1 (<1). However, *G. africanum* and *T. triangulare* had 0.9101 and 0.7298 hazard index, which were nearer to one. *V. amygdaline* had the lowest hazard index, while *G. latifolium* had the highest hazard index. *T. occidentalis* and *A. hybridas* had a high concentration of iron and G. latifolium had the highest concentration of manganese (2.432 + or – 0.003^{h} ppm) and it is as a result of contamination from use of polluted water for cultivation, use of pesticides, fertilizers e.t.c (Gokulakrishnan and Balamurugan, 2010)). In humans, Manganese is associated with bone development, metabolism of amino acid, lipid, and carbohydrate. However, when in excess, it can cause manganism, a condition similar in effect to Parkinson's disease. Iron is a major component of Fe-heme proteins such as hemoglobin, Fe-sulphur enzymes (fumarate reductase), proteins for iron (Fe) storage and transport (transferrin and ferritin), and other Fe-containing or Fe activated enzymes such as NADH dehydrogenase and succinate. One of the most serious forms of iron body burden is acute iron poisoning (Gezahegn *et al.*, 2007).

The risk of having cancer after prolonged consumption of vegetables laden with heavy metals was calculated and presented in Table 5. Lead and Nickel had no cancer risk in the studied vegetables. The cancer risk of vegetables - *P. guineese, G. latifolium,* and *P. mildbraedi* were similar but falls below 10^{-6} (ILCR<10^{-6}). Results showed that Chromium and Cadmium in vegetables had cancer risk below the level of acceptable cancer risk. *P. guineense* had the highest cancer risk relative to *P. mildbraedi* and *T. occidentalis* with the lowest values. Carcinogenic Risk (CR) can be estimated and expressed as a probability or the chance of incurring cancer over a lifetime of about 70 years. The average value of cancer risk for all the vegetables did not show carcinogenicity, therefore, it is correct to suggest its safety upon consumption. Comparing with the already established guideline values, data from this study suggests that *P. Schum* collected from Ubani market may not be safe for consumption as it shows high cancer risk with the probability of causing cancer over a lifetime of about 70 years.

In Table 6, the total cancer risk of heavy metals in vegetables have close values, except *T. occidentalis.* The total cancer risk of vegetables are in descending order, beginning with *T. occidentalis > V. amygdaline > P. guineense > A. hydridus > G. africanum > S. macrocarpon > O. gratissimum > T.triangulare > P. mildbraedi > G. latifolium.* The highest is *T. occidentalis* and the lowest is *G.latifolium.* Since the vegetable samples *G. africanum, G. latifolium, and T. triangulare* are harmful to humans, consumers should regularly engage in timely assessment of their health. Dietary exposure to several heavy metals including Ni, Cd, Cr, Co, Pb, As, Hg, Zn, and Cu, has been recognized as a risk to human health through the consumption of vegetable (Tasrina *et al.*, 2015). No matter how low the heavy metals concentration

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may be in vegetables, their presence are not desirable. Therefore, it is strongly advised that people should not consume large quantities of these vegetables in order to avoid accumulations of heavy metals in their body.

Table 5. *Cancer risks of heavy metals in vegetables*

Vegetables	Ni	Cr	Cd	Pb
G. africanum	8.5E-04	1.0E-04	2.4E-05	-
V. amygdalina	1.6E-04	2.1E-04	3.1E-05	-
T. triangulare	7.7E-04	5.5E-04	3.8E-05	-
S. macrocarpon	6.5E-04	1.7E-04	4.2E-05	-
O. gratissimum	6.5E-04	5.5E-04	4.6E-05	-
G. latifolium	9.9E-04	5.5E-04	4.6E-05	-
P. mildbraedi	9.9E-04	3.7E-04	5.3E-05	-
T. occidentalis	-	4.7E-04	5.3E-05	-
A. hybridus	3.1E-04	3.4E-04	4.9E-05	-
P. guineense	1.3E-04	3.9E-05	4.9E-05	-

The level of acceptable cancer risk (ILCR) for the regulatory purpose is $10^{-6} – 10^{-4}$

Table 6. *Total cancer risk of heavy metals in vegetables*

Vegetables	Total cancer risk
G.africanum	11.9E-13
V.amygdaline	6.8E-13
T.triangulare	17E-13
S. macrocarpon	12.4E-13
O. gratissimum	16.6E-13
G.latifolium	20E-13
P. mildbraedi	18.9E-13
T. occidentalis	10E-9
A.hydridus	11.4E-13
P.guineense	10.1E-13

The level of acceptable cancer risk (ILCR) for the regulatory purpose is $10^{-6} – 10^{-4}$

Conclusions

In vegetables, the target hazard quotient of *G. africanum, and T. triangulare* equals the set standards. The findings on the average daily intake (ADI), hazard quotient (HQ), and hazard index (HI) revealed the risk of cancer upon ingestion of *G. latifolium.* This could be due to the high concentration of copper, nickel, chromium, cadmium, and manganese. Meanwhile, the vegetables deemed to be safe for consumption are *V. amygdalina*, *S. macrocarpon, O. gratissimum, P. mildbraedi, T. occidentalis, A. hybridus,* and *P. guineese*, respectively.

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Author's contribution

All author performed equally during the investigation.

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