HEAVY METAL CONTENT AND THE POTENTIAL HEALTH RISK ASSESSMENT OF SOME LEAFY VEGETABLES CULTIVATED IN SOME FLOODPLAINS AND FARMLANDS IN LAGOS, NIGERIA

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Abstract

The objectives of this study were to investigate heavy metal accumulation (Pb, Cr, Zn, Cd, Ni and Cu) in vegetable species (*Telferia occidentalis*, *Talinum triangulare*, *Ocimum gratissimum*, *Celosia argentea*, and *Amaranthus viridis*) cultivated in farmlands and floodplains, and to assess the human health risks of the daily intake of heavy metals through consumption. This study indicated that the heavy metals in the vegetables were below the safe limits of 40 mg/kg, 20 mg/kg, and 70-80 mg/kg for copper (Cu), zinc (Zn), and nickel respectively as set by the WHO/FAO and USFDA while cadmium (Cd) lead (Pb) and chromium (Cr) were above standard limit. The daily intake of metals in vegetables species for Cd (0.003 – 0.040 mg/kg), Pb (0.33 – 0.57), and Cu (0.550 – 0.997 mg/kg) are higher than the recommended daily intake of metals but do not exceed the upper tolerable daily level. While Zn and Ni fall below the recommended daily intake of metals in vegetables. The health risk index result showed high values for Cd, Pb, Zn, Ni and Cu while low value for Cr and it implies that Cd, Pb, Zn, Ni and Cu could pose low health risk to people consuming these leafy vegetables. The target hazard quotient (THQ) in all metals is far less than 1 in all the vegetables species; however, it might pose serious health risk concern over a lifetime of consumption when other routes of heavy metal intake are considered.

Keywords: vegetables, heavy metals, health risk index, farmlands, daily metal intake.
1. Introduction

Vegetables are important edible crops and are an essential part of the human diet. They are rich in nutrients required for human health, and are an important source of carbohydrates, vitamins, minerals, and fibers (Zhou et al., 2016). They are herbaceous plants whose part or parts are eaten as supporting food or main dishes and they may be aromatic, bitter or tasteless, and their nutrient content varies considerably (Mensah et al., 2008). Heavy metals in vegetables are of growing concerns ever since some soils and irrigation waters are been observed to be polluted (Sipter et al., 2008). Vegetables easily take up heavy metals even when in low level and accumulate them in their edible parts (Jolly et al., 2013). Once vegetables containing high levels of heavy metals are consumed by human, such metals can cause several clinical and physiological problems (Kumar et al., 2007; Khan et al., 2008).

Heavy metals refer to any metallic element that has a relative density greater than 4g/cm³ (Lide, 1992). Heavy metals among others include; lead (Pb), cadmium (Cd), zinc (Zn), mercury (Hg), arsenic (As), silver (Ag), chromium (Cr), copper (Cu), iron (Fe) and the platinum group elements. They are non-biodegradable and persistent environmental contaminants which may be deposited on the soil surface and then adsorbed by plants into their tissues (Adesuyi et al., 2015; Adesuyi et al., 2016). They can accumulate in the food chain with risks to the health of animals and humans which are less sensitive to metal toxicity compared to plants but are capable of concentrating heavy metals. It should be realized that most of these cultivated lands are contaminated with heavy metals contributed mainly through vehicular emissions, pesticides and fertilizers, industrial effluents and other anthropogenic activities which have resulted in the growth and harvesting of contaminated vegetables (Rattan et al., 2005; Sanayei et al. 2009).

In many countries and regions, vegetables are exposed to heavy metals by various means with different dosage of contaminant. Akinola and Njoku (2007) reported high and moderate pollution of Cd and Pb of cultivated plants in the mudflat of Abule Ado floodplain in Lagos, Nigeria. In Hong Kong, Hu et al. (2013) reported that 16%, 26%, and 0.56% of market vegetables were contaminated by Pb, Cd, and Cr, respectively. Tsafe et al. (2012) reported Pb, Cu, Zn, Cr, Cd and Fe concentration of 29.66 mg/kg, 1.13 mg/kg, 68.91 mg/kg, 16.73 mg/kg, 0.97 mg/kg and 195.25 mg/kg respectively in
vegetables grown in Yargalma, Northern Nigeria. In Huludao City, China, the ranges of Pb and Cd concentrations in vegetables are 0.003 to 0.624 mg/kg and 0.003–0.195 mg/kg (fresh weight), respectively, and the maximum concentrations of Pb and Cd all exceeded the recommended values (Zheng et al., 2007). Rahman et al. (2014) reported that some Australian and Bangladeshi vegetables contained Cd concentrations higher than the Australian standard maximum limit (0.1 mg/kg). Moreover, vegetable consumption is now considered to be one of the major sources of heavy metal intake for humans, and elevated levels of heavy metal in edible parts of vegetables can affect human health.

The Commission of the European Communities and the Codex Alimentarius Commission (2001) set the maximum limit (ML) for Cadmium as 0.2 mg/kg for leafy vegetables and fresh herbs, 0.1 mg/kg for stem and root vegetables and 0.05 mg/kg for the remaining ungrouped vegetables. For lead, both organizations set the ML of 0.3 mg/kg for brassicas, leafy vegetables and herbs, and 0.1 mg/kg for all remaining vegetables (Kachenko and Singh, 2006). Severe exposure of Cd may result in pulmonary effects such as emphysema, bronchiolitis and alveolitis. Renal effects may also result due to subchronic inhalation of Cd (Young, 2005). Pb toxicity causes reduction in the haemoglobin synthesis, disturbance in the functioning of kidney, joints, reproductive and cardiovascular systems and chronic damage to the central and peripheral nervous systems (Ogwuegbu and Muhanga, 2005; Singh et al., 2010). Higher concentration of Zn can cause impairment of growth and reproduction (Nolan, 2003; Adesuyi et al., 2015). Considering the potential toxicity and cumulative behaviour of heavy metals, frequent consumption of cultivated vegetables, safety aspect of foods and the awareness of the people, more research work is still needed to be done on all species of vegetables grown and consumed in Nigeria. Thus, this study was designed and carried out to quantify the concentration and accumulation of Cd, Pb, Zn, Cr, Ni and Cu in five most consumed leafy vegetable species cultivated in farmlands and floodplains in Lagos, Nigeria; to assess the daily intake of these metals and the health risks of vegetable consumption on residents.

2. Materials and Methods

2.1 Sample Collection
Fresh samples of five (5) commonly consumed vegetables were obtained from 2 cultivated farmlands: LASPOTECH in Ikorodu (6°38.7966’N/3°31.4538’E) and Oke Afa in Isolo (6°31.9212’N/3°18.54’E) and 2 floodplains: Abule Ado in Amuwo odofin (6°27.582’N/3°15.3378’E) and LASU in Ojo (6°28.4274’N/3°12.18’E) in Lagos metropolis, Nigeria. The details of the vegetable species, local names and parts of vegetables used for analysis are shown in Table 1. The samples were properly tagged according to farmlands and floodplains in polythene bags and taken to the Herbarium of the Department of Botany, University of Lagos for identification, and subsequently taken to the laboratory for digestion and analyses of heavy metal contents.

### Table 1: Vegetables used in this study

<table>
<thead>
<tr>
<th>S/n</th>
<th>Botanical name</th>
<th>Family</th>
<th>Local name</th>
<th>Parts used/consumed</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td><em>Telferia occidentalis</em></td>
<td><em>Cucurbitaceae</em></td>
<td>Fluted pumpkin</td>
<td>Stems and leaves</td>
</tr>
<tr>
<td>2</td>
<td><em>Talinum triangulare</em></td>
<td><em>Portulaceae</em></td>
<td>Waterleaf</td>
<td>Stems and leaves</td>
</tr>
<tr>
<td>3</td>
<td><em>Ocimum gratissimum</em></td>
<td><em>Lamiaceae</em></td>
<td>Scent leaf</td>
<td>Leaves and tender stems</td>
</tr>
<tr>
<td>4</td>
<td><em>Celosia argentea</em></td>
<td><em>Amaranthaceae</em></td>
<td>Plumed cockscomb</td>
<td>Stems and leaves</td>
</tr>
<tr>
<td>5</td>
<td><em>Amaranthus viridis</em></td>
<td><em>Amaranthaceae</em></td>
<td>Slender amaranth</td>
<td>Stems and leaves</td>
</tr>
</tbody>
</table>

### 2.2 Sample Preparation

The vegetables were washed up with tap water thoroughly to remove the attached dust particles, soil, unicellular algae, etc. Then they were 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 and 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 analysis.

### 2.3 Digestion and Metal Analysis

0.5 g of each samples was measured into a clean dried beaker (100ml), 10 ml of acidic mixture of HNO₃/HClO₄ in ratio 2:1 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 up to a final volume of 25 ml with deionised water. The digested samples were kept at 4°C prior to analysis. A buck scientific atomic absorption spectrophotometer with model 210VGP was used for lead (Pb), chromium (Cr), zinc (Zn), cadmium (Cd), nickel (Ni) and copper (Cu) analysis (MMAF, 2005).

2.4 Health risk assessment
The potential health risks of heavy metal consumption through vegetables were assessed based on the daily intake of metal (DIM), health risk index (HRI), and the target hazard quotient (THQ).

The daily intake of metal in this study was calculated based on the formula below:

\[
DIM = \frac{C_{metal} \times C_{factor} \times C_{foodintake}}{B_{averageweight}} - (1) \text{ (Chary et al., 2008)}
\]

Where, \(C_{metal}\) is the heavy metals concentration in vegetables (mg/kg), \(C_{factor}\) is the conversion factor, \(C_{foodintake}\) is the daily intake of vegetables and \(B_{averageweight}\) is the average body weight for adult’s vegetable consumer. The conversion factor of 0.085 was used to convert fresh vegetable weight to dry weight (Khan et al., 2009), the daily intake of vegetables for adult south western Nigerian is assumed to be 65 g (Oguntona, 1998), while the average body weight of adult vegetable consumer used was 65 kg for this study (Tsafe et al., 2012).

The health risk index (HRI) was calculated using the formula below:

\[
HRI = \frac{DIM}{R_{FD}} - (2) \text{ (Jan et al., 2010)}
\]

Where DIM is the daily intake of metal and \(R_{FD}\) is the oral reference dose (Pb, Cd, Cu, Zn, Cr and Ni values were 0.0035 mg/kg/day, 0.001 mg/kg/day, 0.040 mg/kg/day, 0.300 mg/kg/day, 1.5 mg/kg/day and 0.020 mg/kg/day, respectively) (USEPA IRIS, 2006; Hang et al., 2009; Bortey-Sam et al., 2015).

The THQ was calculated using the formula below:

\[
THQ = \frac{E_F \times E_D \times F_{IR} \times C}{R_{FD} \times W_{AB} \times T_A} \times 10^{-3} - (3) \text{ (Wang et al., 2005; Storelli, 2008)}
\]

where \(E_F\) is the exposure frequency (350 days/year); \(E_D\) is the exposure duration (54 years, equivalent to the average lifetime of the Nigerian population); \(F_{IR}\) is the food ingestion rate (vegetable consumption values for adult south western Nigerian is 65 g/person/day) (Oguntona, 1998); \(C\) is the metal concentration in the edible parts
of vegetables (mg/kg); $R_{FD}$ is the oral reference dose (Pb, Cd, Cu, Zn, Cr and Ni values were 0.0035 mg/kg/day, 0.001 mg/kg/day, 0.040 mg/kg/day, 0.300 mg/kg/day, 1.5 mg/kg/day and 0.020 mg/kg/day, respectively) (USEPA IRIS, 2006; Hang et al., 2009; Bortey-Sam et al., 2015); $W_{AB}$ is the average body weight (65 kg for adults vegetable consumer in South western Nigeria) (Oguntona, 1998); and $T_a$ is the average exposure time for non-carcinogens ($E_d \times 365$ days/year). If the THQ value is greater than 1, the exposure is likely to cause obvious adverse effects.

3. Statistical analyses
A one-way ANOVA was used to evaluate the differences among vegetable species. Duncan’s test was used to detect the significant differences between the means of different vegetable classifications. The criterion for significance in the procedures was set at $p < 0.05$ (significant). All statistical analysis was done using Graph pad prism, version 6.0.

4. Results and Discussion
4.1 Heavy metals concentration in Vegetables
Different vegetables may accumulate different heavy metals, and the absorption ability varies in different biological species due to their diverse physiological character (Adedokun et al., 2016). The results obtained from the vegetable samples collected from the various farms around Lagos State for Cd, Pb, Zn, Cr, Ni and Cu are shown in Table 2. The recommended limits for various heavy metals vary depending on the food being considered and the country. The recommended maximum limit of cadmium, chromium, lead and copper for vegetables by FAO/WHO (2001) was set as 0.2 mg/kg, 2.3 mg/kg, 0.3 mg/kg and 40 mg/kg respectively (Maleki and Zarasvand, 2008). The Chinese Department of Protective Medicines (1994) also has the safe limit for lead in vegetable as 0.2 mg/kg and 20 mg/kg for Zinc (Asdeo and Loonker, 2011).

The concentrations of Cd in the vegetables from the farms and floodplain ranged between 0.175 mg/kg in $O. gratissimum$ from Abule Ado floodplain and 0.325 mg/kg in also $O. gratissimum$ from LASU floodplain. Differing values have been previously reported in leafy vegetables which include 0.916 mg/kg for bitter leaf by Sobukola et al. (2010) and 0.049 mg/kg by Muhammad et al. (2008) for lettuce. The concentration of Cd in this study is higher than in these previous studies and also above the permissible levels by FAO/WHO (2001) in vegetable (0.2 mg/kg). Primary source of Cadmium (Cd) in human body is through consumption of
food grown in contaminated areas (Turkdogan et al., 2002). Cadmium is a non-essential element in foods and natural waters and it accumulates primarily in the kidneys and has a long biological half-life in humans of 10-35 years. Critical cadmium level in the kidney of 200 mg/kg is capable of causing renal failure in adults; however this condition occurs after a daily dietary intake of about 175 mg per person for 50 years (Oladele and Fadare, 2015).

The highest Pb concentration in vegetables obtained from farms and floodplains was recorded in O. gratissimum (1.075 mg/kg) from LASU floodplain and the least in O. gratissimum (0.125 mg/kg) from Oke Afa. In this study, the concentrations of Pb are quite generally and statistically higher (p<0.05) than the permissible levels by FAO/WHO in vegetables of 0.3 mg/kg. The high levels of lead in some plants may probably be attributed to pollutants in irrigation water, farm soil or due to pollution from the highways traffic and industrial sites located around the sampled locations (Akinola and Njoku et al., 2007). Leafy vegetables from open field have been documented to possess higher concentrations of Lead (Pb) than vegetables grown in green houses due to anthropogenic sources of contamination (Song et al., 2009). Pb is highly toxic heavy element and its intake via vegetable consumption can cause both acute and chronic poisoning. It has adverse effect on liver, kidney, vascular and immune system (Satter et al., 2016).

Zn is an essential mineral that plays catalytic, structural and regulatory roles as an integral part of many enzymes in human body. It is essential for normal growth, mental ability, immune system, reproduction and healthy function of the heart (Deshpande et al., 2013). The level of Zn in the vegetables from sampled farms ranged between 5.988 mg/kg and 32.425 mg/kg with the highest recorded in A. viridis and the least in O. gratissimum both from LASPOTECH farm in Ikorodu. Zn is quite abundant in all the sampled vegetable species and they are significant. This is similar to levels reported by Akubugwo et al. (2007) in Amaranthus hybridus. Adedokun et al. (2016) also made similar observation in a study of leafy vegetables obtained in some selected markets in Lagos, Nigeria. Consumption of these vegetables could cause nausea, vomiting, loss of appetite, abdominal cramps, diarrhea, headaches and inhibition of copper absorption which sometimes produce copper deficiency and associated anemia (Ngole and Ekosse, 2009).

The concentrations of Cr in the vegetables
from the farms ranged between 0.225 mg/kg in *T. occidentalis* from LASPOTECH farms to 2.33 mg/kg in *C. argentea* from Oke Afa farm while from the floodplains ranged between 0.23 mg/kg in *T. occidentalis* from Abule Ado to 1.66 mg/kg in *C. argentea* from LASU floodplains. Chromium levels in the vegetables sampled varied and are quite higher than the safe limits (2.3 mg/kg) of Cr consumption but not statistically different (p>0.05). These high amounts of Cr might be accumulated in the vegetables due to the contamination of soil, wastewater or industrial effluents (Ramesh et al., 2012). Cr is a trace element necessary for carbohydrate, fat and cholesterol metabolism and important for many hormones and enzyme activity in a certain concentration (up to 200 mg/day) but chronic exposure to Cr may damage liver and kidney (Satter et al., 2016).

*C. argentea* from Abule Ado floodplain had the highest concentration of Ni (3.50 mg/kg) across the farm while *T. occidentalis* from Oke Afa had the least (0.238 mg/kg). Nickel is essential for growth and reproduction in livestock and man, but could be carcinogenic in high amount in the body. In this study, Ni content in vegetables was found to be lower than the estimated maximum guideline set by United State Food and Drug Administration of 70-80 mg/g (Iwegbue, 2010). These variations of Ni contents in various vegetables might be due to the pollutants in soil, air, water, factory wastages, sewerages etc (Satter et al., 2016). Nickel is reported to be a common cause of allergic contact dermatitis (ACD) (Zirwas and Molenda, 2009).

The Cu level of vegetables obtained from farms ranged between 4.87 mg/kg in *C. argentea* from LASPOTECH vegetable farm and 12.613 mg/kg in *O. gratissimum* also from LASPOTECH farm. The Cu levels in the vegetables presented in this study were similar to the levels reported in some common leafy vegetables obtained in four Lagos markets by Adedokun et al. (2016) and vegetables from some farm and market sites in Lagos Nigeria by Doherty et al. (2012) but lower than WHO/FAO (2001) suggested safe limits of 40 mg/kg in adults. Copper is an essential micronutrient which functions as a biocatalyst required for body pigmentation in addition to iron, maintain a healthy central nervous system, prevents anaemia and interrelated with the functions of zinc and iron in the body (Doherty et al., 2012; Adesuyi et al., 2015). Although toxicity of copper is rare, its metabolism is enhanced by molybdenum and zinc constituents in the body (Oladele and Fadare, 2015).
Table 2: Heavy Metal Concentrations in Vegetable Samples from Farms and Markets

<table>
<thead>
<tr>
<th>Vegetables</th>
<th>Abule Ado floodplains</th>
<th>LASPOTECH farm</th>
<th>LASU floodplains</th>
<th>Oke Afa farm</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Cd</td>
<td>Pb</td>
<td>Zn</td>
<td>Cr</td>
</tr>
<tr>
<td>A. viridis</td>
<td>0.2</td>
<td>2</td>
<td>17.</td>
<td>9</td>
</tr>
<tr>
<td>C. argentea</td>
<td>0.3</td>
<td>8</td>
<td>18.</td>
<td>9</td>
</tr>
<tr>
<td>O. gratissimum</td>
<td>0.1</td>
<td>2</td>
<td>17.</td>
<td>20</td>
</tr>
<tr>
<td>T. triangulare</td>
<td>ND</td>
<td>0.2</td>
<td>13.</td>
<td>4.5</td>
</tr>
<tr>
<td>T. occidentalis</td>
<td>ND</td>
<td>0.2</td>
<td>19.</td>
<td>48</td>
</tr>
</tbody>
</table>

FAO/WHO (2001) safe limit for heavy metal consumption in vegetables

<table>
<thead>
<tr>
<th></th>
<th>Cd</th>
<th>Pb</th>
<th>Zn</th>
<th>Cr</th>
<th>Ni</th>
<th>Cu</th>
</tr>
</thead>
<tbody>
<tr>
<td>A. viridis</td>
<td>0.2</td>
<td>0.3</td>
<td>20.0</td>
<td>2.30</td>
<td>-</td>
<td>40</td>
</tr>
</tbody>
</table>

ND- Not detected
4.2 Health risk indices
To assess the health risk of the inhabitants of part of Lagos due to heavy metal intake from vegetables consumption; the daily intake of metals (DIM), health risk index (HRI), and target hazard quotient (THQ) were calculated from equations 1, 2, and 3 respectively and the results are presented in Tables 3, 4 and 5. The daily intake of metals (DIM) 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. This does not take into cognizance the possible metabolic ejection of the metals but can easily tell the possible ingestion rate of a particular metal. The DIM results presented in Table 3 were compared with the recommended daily intake of metals and the upper tolerable daily intake level (UL) established by the Institute of Medicine for people between the ages of 19 to 70 years (FDA, 2001; Garcia-Rico et al., 2007). The degree of toxicity of heavy metals to human being depends upon their daily intake (Singh et al., 2010). The daily intake of metals in vegetables species for Cd (0.003 – 0.040 mg/kg), Pb (0.33 – 0.57), and Cu (0.550 – 0.997 mg/kg) are higher than the recommended daily intake of metals but do not exceed the upper tolerable daily level. While Zn and Ni fall below the recommended daily intake of metals in vegetables. A tolerable daily and upper intake level for Cr in vegetables and foods has not been established. However, calculated DIM value for Cr (0.026 – 0.109 mg/kg) was lower than the recommended oral reference dose (RfD) of 1.5 mg/kg (USEPA, 2010).

Table 3: Daily intake rate (mg person\(^{-1}\) day\(^{-1}\)) of average heavy metals level in vegetables from floodplains and farmlands

<table>
<thead>
<tr>
<th>Vegetables</th>
<th>Population Type</th>
<th>Cd</th>
<th>Pb</th>
<th>Zn</th>
<th>Cr</th>
<th>Ni</th>
<th>Cu</th>
</tr>
</thead>
<tbody>
<tr>
<td>A. viridis</td>
<td>Adults</td>
<td>0.003</td>
<td>0.057</td>
<td>1.500</td>
<td>0.037</td>
<td>0.123</td>
<td>0.721</td>
</tr>
<tr>
<td>C. argentea</td>
<td>Adults</td>
<td>0.000</td>
<td>0.049</td>
<td>1.230</td>
<td>0.109</td>
<td>0.128</td>
<td>0.550</td>
</tr>
<tr>
<td>O. gratissimum</td>
<td>Adults</td>
<td>0.020</td>
<td>0.044</td>
<td>0.984</td>
<td>0.049</td>
<td>0.129</td>
<td>0.997</td>
</tr>
<tr>
<td>T. triangulare</td>
<td>Adults</td>
<td>0.000</td>
<td>0.033</td>
<td>1.116</td>
<td>0.107</td>
<td>0.186</td>
<td>0.807</td>
</tr>
<tr>
<td>T. occidentalis</td>
<td>Adults</td>
<td>0.040</td>
<td>0.033</td>
<td>1.249</td>
<td>0.026</td>
<td>0.098</td>
<td>0.722</td>
</tr>
</tbody>
</table>

**DI (mg day\(^{-1}\) person \(-1\))**

<table>
<thead>
<tr>
<th>*DI (mg day(^{-1}) person (-1))</th>
<th>0.000</th>
<th>0.00</th>
<th>8</th>
<th>-</th>
<th>0.50</th>
<th>0.90</th>
</tr>
</thead>
</table>

**UL (mg day\(^{-1}\) person \(-1\))**

<table>
<thead>
<tr>
<th>*UL (mg day(^{-1}) person (-1))</th>
<th>0.064</th>
<th>0.240</th>
<th>40</th>
<th>-</th>
<th>1.00</th>
<th>10.00</th>
</tr>
</thead>
</table>

*Recommended daily intake (DI) and upper tolerable daily intake (UL) levels of heavy metals in foodstuffs (FDA, 2001; Garcia-Rico et al., 2007)
The calculated HRI values for Cd, Pb, Zn, Cr, Ni, and Cu are shown in Table 4. The HRI for all the vegetables species range as follow; Cd (3.0 to 40.0), Pb (9.43 to 16.29), Zn (3.28 to 5.00), Cr (0.02 to 0.07), Ni (4.90 to 9.30) and Cu (13.75 to 24.93). The HRI result showed high values for Cd, Pb, Zn, Ni and Cu while low value for Cr. Generally, HRI < 1 means that the exposed population is safe of metals health risk while HRI > 1 means the population is unsafe from metal health risk (Khan et al., 2008). Except Cr, the HRI values of all the studied metals are greater than one. This implies that Cd, Pb, Zn, Ni and Cu could pose severe health risk to people consuming these leafy vegetables.

### Table 4: Calculated values of health risk index (HRI) for heavy metals in vegetables from farmlands and floodplains

<table>
<thead>
<tr>
<th>Vegetables</th>
<th>Cd</th>
<th>Pb</th>
<th>Zn</th>
<th>Cr</th>
<th>Ni</th>
<th>Cu</th>
</tr>
</thead>
<tbody>
<tr>
<td>A. viridis</td>
<td>3.00</td>
<td>16.29</td>
<td>5.00</td>
<td>0.03</td>
<td>6.15</td>
<td>18.03</td>
</tr>
<tr>
<td>C. argentea</td>
<td>0.00</td>
<td>14.00</td>
<td>4.10</td>
<td>0.07</td>
<td>6.40</td>
<td>13.75</td>
</tr>
<tr>
<td>O. gratissimum</td>
<td>20.00</td>
<td>12.57</td>
<td>3.28</td>
<td>0.03</td>
<td>6.45</td>
<td>24.93</td>
</tr>
<tr>
<td>T. triangulare</td>
<td>0.00</td>
<td>9.43</td>
<td>3.72</td>
<td>0.07</td>
<td>9.30</td>
<td>20.18</td>
</tr>
<tr>
<td>T. occidentalis</td>
<td>40</td>
<td>9.43</td>
<td>4.16</td>
<td>0.02</td>
<td>4.90</td>
<td>18.05</td>
</tr>
</tbody>
</table>

Target health quotient (THQ) is another tool index used in evaluating a lifetime effect of a particular substance on human health. If THQ is less than 1, there is no obvious risk from the substance over a lifetime of exposure, while if THQ is higher than 1, the substance may produce an adverse effect (Han et al., 1998). The higher the THQ value, the higher the probability of experiencing long term effects. The calculated THQ values for the vegetables are presented in Table 5. The THQ values of the metals ranged from 0.22 – 0.450 (Cd), 0.107 to 0.184 (Pb), 0.037 to 0.056 (Zn), 0.0001 to 0.001 (Cr), 0.055 to 0.105 (Ni), and 0.155 to 0.281 (Cu). This result reflected the risk associated with these heavy metals exposure for the period of life expectancy considered, and the inhabitants are exposed to health risks associated to these metals in the order Cd > Cu > Pb > Ni > Zn > Cr. Copper and zinc, which are important nutrients for humans, are considered a much lower health risk to humans than Pb, and Cd (Alexander et al.,
Poor health can be caused by a lack of these required elements (Zhou et al., 2016), but excessive ingestion can also have adverse effects on human health (Rahman et al., 2014). The THQ in all metals is far less than 1 in all the vegetables species; therefore, it does not pose serious health risk concern over a lifetime of consumption. However, for special populations, such as children, populace with a weak constitution, those that were sensitive, and women that were pregnant, the potential health risks of heavy metal accumulation through vegetable consumption were likely to be higher than for the normal population. Moreover, vegetable consumption was just one part of food consumption. Other foods like fishes, meat, tobacco, rice, and cassava (Adedokun et al., 2016). For Lagos populace, other important route of human exposure to heavy metal maybe considered such as through food consumption, air pollution, drinking water etc (Jolaoso et al., 2016; Njoku et al., 2016). Consequently, the potential health risks for the populace maybe high if other routes were actually considered.

**Table 5:** Calculated values of target hazard quotient (THQ) for heavy metals in vegetables cultivated in farmlands and floodplains

<table>
<thead>
<tr>
<th>Vegetables</th>
<th>Cd</th>
<th>Pb</th>
<th>Zn</th>
<th>Cr</th>
<th>Ni</th>
<th>Cu</th>
</tr>
</thead>
<tbody>
<tr>
<td>A. viridis</td>
<td>0.278</td>
<td>0.184</td>
<td>0.056</td>
<td>0.001</td>
<td>0.070</td>
<td>0.203</td>
</tr>
<tr>
<td>C. argentea</td>
<td>0.00</td>
<td>0.156</td>
<td>0.046</td>
<td>0.001</td>
<td>0.073</td>
<td>0.155</td>
</tr>
<tr>
<td>O. gratissimum</td>
<td>0.220</td>
<td>0.143</td>
<td>0.037</td>
<td>0.001</td>
<td>0.073</td>
<td>0.281</td>
</tr>
<tr>
<td>T. triangulare</td>
<td>0.00</td>
<td>0.107</td>
<td>0.042</td>
<td>0.001</td>
<td>0.105</td>
<td>0.228</td>
</tr>
<tr>
<td>T. occidentalis</td>
<td>0.450</td>
<td>0.107</td>
<td>0.046</td>
<td>0.001</td>
<td>0.055</td>
<td>0.204</td>
</tr>
</tbody>
</table>

**5. Conclusion**

Determination of heavy metals concentration in vegetables is important for health risk assessment during food consumption. This study indicated that the heavy metals in the vegetables were below the safe limits of 40 mg/kg, 20 mg/kg, and 70-80 mg/kg for copper (Cu), zinc (Zn), and Nickel respectively set by the WHO/FAO and USFDA while cadmium (Cd) lead (Pb) and chromium (Cr) were above. It can therefore be concluded that our estimated daily intakes for the heavy metals studied for Cd, Pb, and Cu were higher than the recommended daily intake of metals but do not exceed
the upper tolerable daily level. While Zn and Ni fall below the recommended daily intake of metals in vegetables. The HRI result showed high values for Cd, Pb, Zn, Ni and Cu while low value for Cr. This implies that Cd, Pb, Zn, Ni and Cu could pose severe health risk to people consuming these leafy vegetables. The THQ in all metals is far less than 1 in all the vegetables species; therefore, it does not pose serious health risk concern over a lifetime of consumption if other routes and sources of heavy metals intake are not considered. It is hereby recommended that use of waste water irrigation for cultivation of leafy vegetables in farms and floodplain, and also open farming along high traffic density roads should be discouraged.

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Storelli, M.M. (2008). Potential human health risks from metals (Hg, Cd, and Pb) and polychlorinated biphenyls (PCBs) via seafood consumption: Estimation of target hazard quotients (THQs) and toxic equivalents (TEQs). *Food Chemistry and Toxicology*, 46: 2782–2788.

Heavy metal content ...


