Heavy Metal Concentration Level in Fluted Pumpkin (*Telfairia occidentalis*) Grown Around Obio/Akpor, Rivers State, Nigeria: Its Health Implications

Njoku-Tony RF¹*, Udofia HS¹, Nwoko CO¹, Ihejirika CE¹, Mgbahuruike LU³, Ebe TE¹, Egbuawa IO¹, Ezike MN²

¹Department of Environmental Management, Federal University of Technology, Owerri, Nigeria  
²Department of Animal and Environmental Biology Imo State University, Owerri, Nigeria  
³Department of Environmental Technology, Federal University of Technology, Owerri, Nigeria

*Corresponding Author: Njoku-Tony RF, Federal University of Technology, Owerri, Nigeria, E-mail: tonyrosefeechi@yahoo.com

Received: 27 February 2020; Accepted: 10 March 2020; Published: 26 March 2020


Abstract
This research work assessed the heavy metal concentration of fluted pumpkin (*Telfairia occidentalis*) grown around Obio/Akpor, Rivers state, Southern Nigeria. Vegetable and soil samples were collected from ten different locations and analyzed for Pb, Cr, Cd, Zn, Cu and Fe using Atomic Absorption Spectrophotometer (AAS), Model: Agilent 55B. Heavy metal concentration was in the order: Fe>Zn>Pb>Cu>Cr>Cd. Mean heavy metals concentration in the vegetables ranged as follows: Zn (7.56-36.77 mg/kg), Fe (261.42-416.06 mg/kg), Pb (1.00-2.01 mg/kg), Cd (0.35-0.55 mg/kg), Cu (4.62 mg/kg) and Cr (1.49 mg/kg).

The concentrations of all metals were generally within permissible limits set by WHO/FAO for vegetables except Pb, Cd and Cr in some locations.
Trace pollution index (TPI) was highest in Iriebe followed by Oginigba and Rumuodara. The target hazard quotient (THQ), daily intake of metals (DIM), health risk index (HRI) and hazard index (HI) were computed and was found to be within acceptable limits. However, metal uptake by edible vegetables calls for steady monitoring to avoid concentrations exceeding permissible limits.

**Keywords:** Heavy Metals; *T. occidentalis*; Daily intake of metals (DIM); Health risk index; Target hazard quotient (THQ); Health risk index (HRI); Hazard index (HI)

1. Introduction

Fluted pumpkin (*Telfairia occidentalis*) is an edible vegetable consumed in West Africa especially Nigeria. It is said to be indigenous to the Southern part of Nigeria [1]. It is used in the preparation of the popular Edikang-Ikong soup among the Ibibio/Efiks. Also, it is used in the popular ugu soup among the Igbos. Fluted pumpkin (*T. occidentalis*) is widely known for its nutritional, medicinal and economic values. The plant is tolerant to drought and poor soil. Perennial traits observed in fluted pumpkin (*T. occidentalis*) is the fact that its subsisting underground “tuber” could sprout and produce new plant after the first generation fruits have been harvested. *T. occidentalis* has high content of minerals as iron, sodium, potassium, and phosphorus. They also contain vitamins as thiamine and nicotinamide. Fluted pumpkin (*T. occidentalis*) is important in the treatment of diabetes and anemia. It is also used in the prevention and treatment of osteoporosis because of the presence of calcium which helps in bone calcification. Fluted pumpkin (*T. occidentalis*) is also known to contain phytochemicals like phenol. Phenol and its chemical derivatives are essential in the production of pharmaceutical drugs [2]. *T. occidentalis* is of high demand all over Nigeria perhaps because of its nutritional content. Heavy metals such as Copper (Cu), Cadmium (Cd), Zinc (Zn), Lead (Pb), Chromium (Cr) and Iron (Fe) are commonly found on contaminated sites [3]. Heavy metals such as Cu, Zn and Fe are essential micronutrients for plant metabolism. Both essential and non-essential micronutrients when in excess in the human body pose adverse effect on health. Heavy metals can bioaccumulate in the human body via food chain transfer. These contaminated vegetables can have negative effects on human health. Most heavy metals can be very toxic even at low concentrations because there is no good mechanism for their excretion from the body [4].

Previous authors have noted high heavy metal load on vegetables planted in areas of serious anthropogenic activities [5, 6, 7]. And it has been established that the major cause of heavy metal load in vegetables could be due to its uptake of from polluted soil [8, 9] and exposure of vegetables to air contaminated with heavy metals [10, 11]. Fluted pumpkin (*T. occidentalis*) contaminations by heavy metals has also been reported by [7, 12]. Other vegetable contaminants due to exposure to polluted air include: sulphur and nitrogen oxides, carbon (II) oxide and soot particles [13, 14]. Studies have shown that uncontrolled urban developments have accounted for high levels of heavy metals in the environment. [15] have reported that leafy vegetables accumulate
higher concentration of metals than other food crops. *T. occidentalis* is a major vegetable consumed in the study area, hence, the study investigated concentration of these heavy metals in fluted pumpkin (*T. occidentalis*) and the risk implications.

2. Materials and Methods

2.1 Study area

Obio/Akpor is one of the 23 local governments of Rivers state, south southern part of Nigeria, otherwise called the Niger Delta Region of Nigeria. Obio/Akpor LGA covers about 260 km² (100 sq mi), it is a lowland area with average elevation below 30m above sea level. Its geology comprises basically of alluvia sedimentary basin and basement complex [16, 17]. It is bounded by Ikwerre LGA to the north, Port Harcourt LGA to the south, Oyigbo LGA to the East and Emohua LGA to the West [18]. It is located between latitudes 4° 45’N and 4° 60’N and longitudes 6° 50’E and 8° 00’E. According to population census in 2006 (National Bureau of Statistics, 2006) the total population size of Obio/Akpor LGA was 464,789 [19].

![Map of rivers state showing Obio/Akpor LGA.](image)

**Figure 1:** Map of rivers state showing Obio/Akpor LGA.
Coordinates

Longitudes: 6°53′24″E-7°08′25″E
Latitude: 4°47′24″N-4°55′48″N
Elevation above sea level: 24.8m
Source: Goggle

Figure 2: Map of Obio/Akpor showing study locations.

Obio/Akpor is located in the tropical climate zone with abundant rainfall and little dry season. Rainfall is significant most months of the year, ranging from 2000 and 2500mm with temperature up to 25°C and a relatively constant humidity [19, 17]. The soil is usually sandy or sandy loam and is always leached due to the heavy rainfall experienced in this area [19, 17]. The vegetation is light rainforest and thick mangrove forest with well drained fresh and salt water. Obio/akpor, located in Port Harcourt metropolis is rich in crude oil, it is home for many industries, filling stations, etc. The popularly known Trans Amadi industrial area is located in this area. The inhabitants of the area are the Ikwerre natives of Rivers State. The inhabitants are mainly farmers and traders. Crude oil activities as well as other economic activities have reduced farmlands for farmers.

2.2 Experimental design and sample collection

The study area was stratified into 3 strata based on the anthropogenic activity viz: High industrial activity, heavy traffic highways and rural areas. The sampling area covered the following communities: Choba, Rumuokoro, Iriebe, Oginigba, Rumuokwurushi, Rukpakwulusi, Eliozu, Eneka, Rukpokwu, and Rumuodara as the control. Composite Soil Samples were collected from each stratum at the depth of 0-15cm with soil auger and replicated thrice. Similarly, Fluted Pumpkin (T. occidentalis) were obtained from the wild in each of these communities.
2.3 Materials
The materials used include pH meter, model Janway 3510 used to determine soil pH. Electronic balance (Model:WT5002) used to weigh samples. Atomic Adsorption Spectrometer (Model: Agilent 55B) to determine Cu, Cr, Cd, Zn, Pb and Fe concentrations in both vegetable and soil samples, sharp knife for cutting vegetables and soil auger for soil sample collection.

2.4 Sample preparation
Fluted Pumpkin (*T.occidentalis*) were air-dried and blended to pass through 2mm sieve and was taken to the laboratory for analysis. Soils were also sieved to pass through 2mm and analysed for chemical properties.

2.5 Laboratory analysis
2.5.1 Analytical procedure for trace metal determination: The air-dried vegetable samples were sieved using Whatman Filter Paper (2mm). One gram of each of the vegetable sample was weighed using Electronic balance (Model:WT5002) into a 50ml beaker, 5ml of analytical grade acid HN0₃ and HCl were added. Mixture was allowed to stay for 5mins, and was heated at a temperature of about 80-90°C for one hour thirty minutes using electric hot plate (HP 220, UTEC products Inc., Albany N. Y., USA) until a clear solution was obtained. After cooling, the solution was made up to a final volume (50ml) with distilled water in a glass cylinder and the pH was determined by inserting the pH meter in each of the diluted samples. The Core Cutter method was used to determine the bulk density. The moisture content and dry density of each of the soil samples was also determined [22]. The soil textural class was determined using the wet and dry sieve analysis method [23, 24].

2.6 Method of calculating trace metal pollution index (TPI)
Trace Metal Pollution index was determined using the equation by [9].

\[ TPI= \left( \frac{TC_1 \times TC_2 \times TC_3 \ldots \ldots \cdot TC_n}{n} \right)^{\frac{1}{n}} \]  

Where: TC is the concentration of n trace metals in vegetable samples.
2.7 Methods of calculating health risk parameters

Determination of Target Hazard Quotient (THQ) in Exposed Population

The THQ was calculated using the formula below:

\[ THQ = \frac{EF \times ED \times FIR \times C \times 10^{-3}}{RFD \times WAB \times TA} \]  

Where:
- \( EF \) is the exposure frequency (350 days/year)
- \( ED \) is the exposure duration (54 years, equivalent to the average lifetime of the Nigerian population)
- \( FIR \) is the food ingestion rate (vegetable consumption values for South Western adult Nigerian is 65g/person/day)
- \( C \) is the metal concentration in the edible parts of vegetables (mg/kg)
- \( RFD \) is the oral reference dose (Pb, Cd, Cu, Zn and Cr were 0.0035, 0.001, 0.040, 0.300 and 1.5 mg/kg/day, respectively and the RFD of Fe was 0.65 [26]).
- \( WAB \) is the average body weight (65kg for adult vegetable consumer in South Western Nigeria)
- \( TA \) is the average exposure time for non-carcinogens (ED x 365 days/year).

2.8 Determination of daily intake of metal (DIM) in exposed population

The DIM was calculated using the equation below:

\[ DIM = \frac{C_{metal} \times C_{factor} \times C_{foodintake}}{B_{averageweight}} \]  

Where:
- \( C_{metal} \) is the heavy metal concentration in vegetables (mg/kg)
- \( C_{factor} \) is the conversion factor (0.085). The conversion factor of 0.085 is to convert fresh vegetable weight to dry weight.
- \( C_{foodintake} \) is the daily intake of vegetables which was 65g/day.
- \( B_{averageweight} \) is the average body weight, which was 65kg for this study.

2.9 Determination of health risk index (HRI) in exposed population

The HRI was calculated using the formula below:

\[ HRI = \frac{DIM}{RFD} \]  

2.10 Determination of health index (HI) in exposed population

The HI was calculated using the formula below [27]

\[ HI = \sum THQ_{1} + THQ_{2} + THQ_{3} + \ldots + THQ_{n} \]  

2.11 Statistical analysis

Data generated were subjected to statistical analysis using Minitab statistical package version 16. One way analysis of variance (ANOVA) was used to partition means and significant means were grouped by Tukey’s multiple range tests at 5% significant probability level.

3. Results

3.1 Concentrations of heavy metals in fluted pumpkin in the study area

Trace metal contamination of fluted pumpkin ranged from Cu:0.00 ± 0.00-4.62 ± 0.04mg/kg, Cr:0.00 ± 0.00-1.49 ± 0.0104mg/kg, Cd:0.00 ± 0.00-0.55 ± 0.0104mg/kg, Zn:7.56 ± 0.01-36.77 ± 0.0204mg/kg, Pb:0.00 ± 0.00-2.01 ± 0.0104mg/kg and Fe: 261.42 ± 0.01-416.06 ± 0.0104mg/kg (Table 1).
Table 1: Heavy metal concentration (mg/kg) of fluted pumpkin in the study area.

<table>
<thead>
<tr>
<th>S/No</th>
<th>Location</th>
<th>Cu(mg/kg)</th>
<th>Cr(mg/kg)</th>
<th>Cd(mg/kg)</th>
<th>Zn(mg/kg)</th>
<th>Pb(mg/kg)</th>
<th>Fe(mg/kg)</th>
<th>TP1</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Rumuokoro</td>
<td>ND</td>
<td>ND</td>
<td>0.35 ± 0.00</td>
<td>36.77 ± 0.02</td>
<td>1.51 ± 0.01</td>
<td>298.01 ± 0.01</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>Rumuokwurushi</td>
<td>ND</td>
<td>1.49 ± 0.01</td>
<td>ND</td>
<td>24.12 ± 0.01</td>
<td>ND</td>
<td>382.51 ± 0.01</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>Iriebe</td>
<td>ND</td>
<td>ND</td>
<td>0.35 ± 0.00</td>
<td>36.77 ± 0.02</td>
<td>1.51 ± 0.01</td>
<td>416.06 ± 0.01</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>Oginigba</td>
<td>ND</td>
<td>ND</td>
<td>0.35 ± 0.00</td>
<td>36.77 ± 0.02</td>
<td>1.51 ± 0.01</td>
<td>384.72 ± 0.01</td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>Eliozu</td>
<td>ND</td>
<td>ND</td>
<td>0.55 ± 0.01</td>
<td>30.20 ± 0.01</td>
<td>ND</td>
<td>275.61 ± 0.01</td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>Choba</td>
<td>ND</td>
<td>ND</td>
<td>ND</td>
<td>10.13 ± 0.06</td>
<td>ND</td>
<td>287.41 ± 0.01</td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>Eneka</td>
<td>ND</td>
<td>ND</td>
<td>0.35 ± 0.00</td>
<td>20.43 ± 0.01</td>
<td>1.00 ± 0.00</td>
<td>357.71 ± 0.01</td>
<td></td>
</tr>
<tr>
<td>8</td>
<td>Rumuodara</td>
<td>ND</td>
<td>ND</td>
<td>ND</td>
<td>7.56 ± 0.01</td>
<td>ND</td>
<td>261.42 ± 0.01</td>
<td></td>
</tr>
<tr>
<td>9</td>
<td>Rukpakwulsi</td>
<td>ND</td>
<td>ND</td>
<td>0.45 ± 0.00</td>
<td>21.08 ± 0.01</td>
<td>ND</td>
<td>296.86 ± 2.32</td>
<td></td>
</tr>
<tr>
<td>10</td>
<td>Rukpokwu</td>
<td>4.62 ± 0.04</td>
<td>ND</td>
<td>ND</td>
<td>29.24 ± 0.01</td>
<td>ND</td>
<td>273.62 ± 0.01</td>
<td></td>
</tr>
</tbody>
</table>

Columns bearing the same letters are not significantly different at 5% probability level; ND = Not Detected.

The trace metal pollution index (TPI) recorded the highest value (21.00) in Oginigba followed by Choba (19.92) and Rumuokwurushi (14.27).

Table 2: Heavy metal concentration (mg/kg) of soil in the study area.

<table>
<thead>
<tr>
<th>Location</th>
<th>Cu(mg/kg)</th>
<th>Cr(mg/kg)</th>
<th>Cd(mg/kg)</th>
<th>Zn(mg/kg)</th>
<th>Pb(mg/kg)</th>
<th>Fe(mg/kg)</th>
<th>TPI</th>
</tr>
</thead>
<tbody>
<tr>
<td>Choba</td>
<td>8.60 ± 0.01</td>
<td>12.77 ± 0.03</td>
<td>3.45 ± 0.002</td>
<td>27.03 ± 0.06</td>
<td>5.00 ± 0.01</td>
<td>857.69 ± 0.01</td>
<td>19.92</td>
</tr>
<tr>
<td>Rumuokwurushi</td>
<td>9.81 ± 0.01</td>
<td>19.95 ± 0.01</td>
<td>0.35 ± 0.001</td>
<td>15.82 ± 0.01</td>
<td>6.50 ± 0.01</td>
<td>875.47 ± 0.03</td>
<td>14.27</td>
</tr>
<tr>
<td>Oginigba</td>
<td>17.51 ± 0.01</td>
<td>17.93 ± 0.06</td>
<td>0.50 ± 0.006</td>
<td>51.50 ± 0.01</td>
<td>8.50 ± 0.00</td>
<td>873.37 ± 0.06</td>
<td>21.00</td>
</tr>
</tbody>
</table>

Columns bearing the same letters are not significantly different at 5% probability level. pH varied from 8.943 ± 0.006-9.033 ± 0.006, Electrical Conductivity (EC) varied from 8020.3 ± 0.6-11140.3 ± 0.6µS/cm,
Cation Exchange Capacity varied from $0.017 \pm 0.000115$ to $0.024 \pm 0.000058$ Meq/100g. Total Organic Carbon (TOC) varied from $22.31 \pm 0.0115$ mg/g and Bulk Density varied from $1.38 \pm 0.00115$ to $1.51 \pm 0.00577$ g/cm$^3$ (Table 3).

<table>
<thead>
<tr>
<th>Location</th>
<th>pH</th>
<th>EC (µS/cm)</th>
<th>CEC Meq/100g</th>
<th>Total N (%)</th>
<th>TOC (mg/g)</th>
<th>Bulk Density (g/cm$^3$)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Choba</td>
<td>$8.963 \pm 0.06^a$</td>
<td>$11140.3 \pm 0.6^a$</td>
<td>$0.022 \pm 0.017^b$</td>
<td>$0.18 \pm 0.058^b$</td>
<td>$22.31 \pm 0.0115^a$</td>
<td>$1.51 \pm 0.0577^a$</td>
</tr>
<tr>
<td>Rumuokwurushi</td>
<td>$9.033 \pm 0.06^a$</td>
<td>$8380.7 \pm 0.6^a$</td>
<td>$0.017 \pm 0.0115^a$</td>
<td>$0.06 \pm 0.0115^a$</td>
<td>$33.20 \pm 0.058^a$</td>
<td>$1.38 \pm 0.0115^a$</td>
</tr>
<tr>
<td>Oginigba</td>
<td>$8.943 \pm 0.06^c$</td>
<td>$8020.3 \pm 0.6^c$</td>
<td>$0.024 \pm 0.0058^b$</td>
<td>$0.22 \pm 0.0115^a$</td>
<td>$37.93 \pm 0.0577^a$</td>
<td>$1.51 \pm 0.0577^a$</td>
</tr>
</tbody>
</table>

Table 3: Soil chemical characteristics of the study area.

<table>
<thead>
<tr>
<th>Soil Properties</th>
<th>Cu</th>
<th>Cr</th>
<th>Cd</th>
<th>Zn</th>
<th>Pb</th>
<th>Fe</th>
</tr>
</thead>
<tbody>
<tr>
<td>pH</td>
<td>$-0.57$</td>
<td>$0.549$</td>
<td>$-0.344$</td>
<td>$-0.861$</td>
<td>$-0.289$</td>
<td>$0.404$</td>
</tr>
<tr>
<td></td>
<td>$0.109^{ns}$</td>
<td>$0.126^{ns}$</td>
<td>$0.365^{ns}$</td>
<td>$0.003$</td>
<td>$0.451^{ns}$</td>
<td>$0.281^{ns}$</td>
</tr>
<tr>
<td>EC</td>
<td>$-0.685$</td>
<td>$-0.928$</td>
<td>$0.989$</td>
<td>$-0.312$</td>
<td>$-0.878$</td>
<td>$-0.977$</td>
</tr>
<tr>
<td></td>
<td>$0.042$</td>
<td>$0.000$</td>
<td>$0.000$</td>
<td>$0.414^{ns}$</td>
<td>$0.002$</td>
<td>$0.000$</td>
</tr>
<tr>
<td>CEC</td>
<td>$0.621^{ns}$</td>
<td>$-0.503$</td>
<td>$0.291$</td>
<td>$0.894$</td>
<td>$0.347$</td>
<td>$-0.352$</td>
</tr>
<tr>
<td></td>
<td>$0.074^{ns}$</td>
<td>$0.167^{ns}$</td>
<td>$0.448^{ns}$</td>
<td>$0.001$</td>
<td>$0.360^{ns}$</td>
<td>$0.353^{ns}$</td>
</tr>
<tr>
<td>Total Nitrogen</td>
<td>$0.600^{ns}$</td>
<td>$-0.527$</td>
<td>$0.317$</td>
<td>$0.882$</td>
<td>$0.321$</td>
<td>$-0.378$</td>
</tr>
<tr>
<td></td>
<td>$0.088^{ns}$</td>
<td>$0.145^{ns}$</td>
<td>$0.406^{ns}$</td>
<td>$0.002$</td>
<td>$0.399^{ns}$</td>
<td>$0.317^{ns}$</td>
</tr>
<tr>
<td>Total Organic Carbon</td>
<td>$0.812^{ns}$</td>
<td>$0.839$</td>
<td>$-0.942$</td>
<td>$0.489$</td>
<td>$0.953$</td>
<td>$0.918$</td>
</tr>
<tr>
<td></td>
<td>$0.008$</td>
<td>$0.005$</td>
<td>$0.000$</td>
<td>$0.182^{ns}$</td>
<td>$0.000$</td>
<td>$0.000$</td>
</tr>
<tr>
<td>Bulk Density</td>
<td>$0.387^{ns}$</td>
<td>$-0.715$</td>
<td>$0.536$</td>
<td>$0.740$</td>
<td>$0.082$</td>
<td>$-0.590$</td>
</tr>
<tr>
<td></td>
<td>$0.303^{ns}$</td>
<td>$0.030$</td>
<td>$0.137^{ns}$</td>
<td>$0.023$</td>
<td>$0.834^{ns}$</td>
<td>$0.095^{ns}$</td>
</tr>
</tbody>
</table>

ns = not significant; pH was not significant in all the trace metals apart from zinc and ranged from $0.003-0.451$, electrical conductivity was significant in all the trace metals apart from zinc and ranged from $0.000-0.414$, cation exchange capacity was not significant in all the trace metals except in cadmium and ranged from $0.001-0.448$, total nitrogen was not significant in all the trace metals except in zinc and ranged from $0.002-0.406$ and total organic carbon was significant in all the trace metals except in zinc and ranged from $0.000-0.182$ (Table 4).

Table 4: Relationships between soil chemical properties and heavy metal uptake in plants.
3.2 Results of calculated health risk parameters
The THQ ranged from 0.001-0.477 (Table 5)
The HI value was 1.508 (Table 4.5)
The HRI ranged from 0.085-42.289 (Table 5).

<table>
<thead>
<tr>
<th>Heavy Metal</th>
<th>THQ</th>
<th>HRI</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cu</td>
<td>0.111</td>
<td>9.825</td>
</tr>
<tr>
<td>Cr</td>
<td>0.001</td>
<td>0.085</td>
</tr>
<tr>
<td>Cd</td>
<td>0.432</td>
<td>38.000</td>
</tr>
<tr>
<td>Zn</td>
<td>0.074</td>
<td>6.593</td>
</tr>
<tr>
<td>Pb</td>
<td>0.413</td>
<td>36.57</td>
</tr>
<tr>
<td>Fe</td>
<td>0.477</td>
<td>42.289</td>
</tr>
<tr>
<td>HI = ΣTHQ</td>
<td>1.508</td>
<td></td>
</tr>
</tbody>
</table>

**Table 5:** THQ and HI of Telfairiaoccidentalis in exposed population.

3.2 Results of calculated health risk parameters
The THQ ranged from 0.001-0.477 (Table 5)
The HI value was 1.508 (Table 4.5)
The HRI ranged from 0.085-42.289 (Table 5).

<table>
<thead>
<tr>
<th>Heavy Metal</th>
<th>DIM (mg day⁻¹ person⁻¹)</th>
<th>* DI (mg day⁻¹ person⁻¹)</th>
<th>* UL (mg day⁻¹ person⁻¹)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cu</td>
<td>0.393</td>
<td>0.9</td>
<td>10</td>
</tr>
<tr>
<td>Cr</td>
<td>0.127</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Cd</td>
<td>0.038</td>
<td>0.000</td>
<td>0.064</td>
</tr>
<tr>
<td>Zn</td>
<td>1.978</td>
<td>8</td>
<td>40</td>
</tr>
<tr>
<td>Pb</td>
<td>0.128</td>
<td>0.000</td>
<td>0.240</td>
</tr>
<tr>
<td>Fe</td>
<td>27.488</td>
<td>8</td>
<td>45</td>
</tr>
</tbody>
</table>

* Recommended daily intake (DI) and upper tolerable daily intake (UL) levels of heavy metals in foodstuffs (FDA, 2001; [28]; The DIM ranged from 0.038-27.488 (Table 6).

**Table 6:** Daily intake rate (mg day⁻¹ person⁻¹) of heavy metal in vegetable.

4. Discussion
4.1 Concentration of heavy metals in *Telfairia occidentalis*
Mean concentration of Pb in the plant samples ranged from 1.00 ± 0.00-2.01 ± 0.01mg/kg. It was found to be highest in Oginigba, followed by Iriebe, Rumuokoro and Eneka with mean values of 2.01mg/kg, 1.51mg/kg, 1.51mg/kg and 1.00mg/kg respectively. These values exceeded the [29] allowable limit of 0.3mg/kg for edible plants [30]. The heavy metal significantly (p<0.05) affected the *Telfairia occidentalis* plant in the study area. Likewise, the soil Pb which ranged from 5.00 ± 0.01-8.50 ± 0.0004mg/kg. The soils of the area were...
significantly affected with heavy metals. The soil Pb value is higher than that of plant. Therefore, the high plant Pb value may be due to absorption of soil lead by plants [7]. This result collaborates the work of [9], who reported that *Telfairia occidentalis* has the ability to absorb lead. Soil Pb in the study area may be due to erosion of Pb based paints, waste from battery and additives from gasoline [31].

Mean concentration of plant Zinc in the study area ranged from 7.56 ± 0.01-36.77 ± 0.0204mg/kg. It was found to be highest in Rumuokoro and lowest in Rumuodara with mean values of 36.77mg/kg and 7.56 respectively. The plant Zinc concentration did not exceed [27] allowable limit of 99.40mg/kg. Similarly, the soil Zinc ranged from 15.82 ± 0.01-51.50 ± 0.0104mg/kg. In this study, the soil Zinc is higher than the plant Zinc concentration. This finding is in agreement with Kalagbor, et al, (2018b) who opined that fluted pumpkin can absorb Zinc. The source of zinc in the study area may be due to steel processing or burning of waste. Although, Zinc is an essential trace element necessary for human health, but high concentrations of zinc can lead to adverse health effects such as anosmia (the loss of the sense of smell) damage to the lungs, liver, kidney, heart and central nervous system [32]

The Cadmium concentration in the plant ranged from 0.35 ± 0.00-0.55 ± 0.0104 mg/kg. It was found in Eliozu, Rukpakwulusi and Rumuokoro with mean values of 0.55mg/kg, 0.45mg/kg and 0.35mg/kg respectively. These values exceeded the WHO/FAO safe limit of 0.2mg/kg for Zn. Result is significant at P<0.05. The soil Cadmium is higher than the plant Cadmium. This result is in line with [9, 33] who found out that Cd exceeded the WHO/FAO safe limit in vegetables. Since the three locations with high Cd levels are areas with high traffic density, the result is also in agreement with [34] who found out that heavy metal contents of vegetable were higher in areas with high traffic routes within Port Harcourt metropolis. The high plant Cd may be due to atmospheric deposition on the plant by vehicular emissions and absorption by plant from soil Cd. The source of Cd in the study area may be due to fossil fuel and cement from construction sites. Cadmium is a metal of great environmental and occupational concern as it has been classified as a known human carcinogen [35]. Also, excessive acute Cadmium exposure may lead to pneumonitis, bronchitis, pulmonary edema and gastrointestinal problem [31].

The plant Chromium was detected in Rumuokwurushi only with value of 1.49 ± 0.0104mg/kg. The plant Cr mean value of 1.49mg/kg is above the [28] allowable limit of 1.30. The soil Chromium concentration significantly (P<0.05) affected the study area and ranged from 12.77 ± 0.03-19.95 ± 0.0104mg/kg. The soil Cr was higher than the plant Cr. This result agrees with [30] who also detected Chromium in vegetable sample. The high plant Cr may be due to the absorption by plant. The source of Cr in the study area may be from welding and other anthropogenic activities. Although, Cr(III) is an essential nutrient for humans, excessive intake can cause skin irritation [36, 37] stomach ulcer, lung problem, kidney and liver damage, reproductive complication and weak immune system [38, 39].
Plant Copper was detected in Rukpokwu only with value of 4.62 ± 0.04mg/kg. The mean Cu value of 4.62mg/kg is less than the [27] safe limit of 73.0mg/kg. However, statistically it is significant at P<0.05. Also, the soil Copper ranged from 8.60 ± 0.01-17.51 ± 0.0104mg/kg. The Cu concentration in the soil significantly differed with that of the plants. This result collaborated the result of [30] who reported that Copper level in vegetable were within safe limits [12], also recorded the presence of Copper in T.occidentalis. The source of Copper in the study area may be linked to waste from electrical gadgets containing copper. Although Copper is an important trace element to living things, but exposure of the body to excessive Copper causes health problems such as immunotoxicity, gastrointestinal disorder, liver and kidney damage [40]. The Iron content in Telfairia occidentalis ranged from 261.42 ± 0.01-416.06 ± 0.0104mg/kg. It was highest in Iriebe. This value was less than the [29] permissible limit of 425.0mg/kg. However, it was significant at P<0.05. Likewise, the concentration of Fe in soil ranged from 857.69 ± 0.01-875.47 ± 0.0304mg/kg. Result showed that this value was significant at P<0.05. The Fe in plant is less than the concentration of Fe in soil. Similarly, this is in line with [30], who also did a similar work in Lagos and found out that Iron was the most abundant metal in the study. Also, [41] did a similar work in Port Harcourt and found out high Iron accumulation in vegetables. The presence of Iron in the study area could be attributed to Iron based waste materials in the area. Iron is very important for the survival of living things but excessive Iron in the body can result in nausea, constipation and reduced zinc absorption [42].

The trace metal pollution index (TPI) of the soil was in the order Oginigba (21.00) >Choba (19.92) >Rumuokwurushi (14.27). These values are relatively high and showed serious soil contamination. Similarly, soil Pb contamination was highest in this area. This may also be the cause of high Pb in fluted pumpkin leaf apart from atmospheric deposition and it may be due to high industrial activities in this location. In terms of location, heavy metal contamination was in the order Iriebe (440.16mg/kg) > Oginigba (417.37 mg/kg) > Rumuokwurushi (408.12 mg/kg) > Eneka (379.14 mg/kg) > Rumuokoro (336.64 mg/kg) > Rukpakwulusi (318.39 mg/kg) > Rukpokwu (307.48 mg/kg) > Rukpakwulusi (306.36 mg/kg) > Choba (297.54 mg/kg) > Rumuodara (268.98). Iriebe recorded highest heavy metal contamination followed by Oginigba. The two areas are areas of serious industrial activities in the study area. Oginigba is the area where the popular T/Amadi is located. However, Rumuodara recorded the least heavy metal contamination. Rumuodara is more of a residential area and the sample was gotten from a garden inside a residential compound, this may be the reason it recorded the least value, however, all the trace metals detected are statistically significant. Also, the trace metals were not evenly distributed across the study area. Zn, Pb and Fe were found in the ten locations. However, Cu was found in Rukpokwu only, Cr was found in Rumuokwurushi only and Cd was found in Rumuokoro, Eliozu and Rukpakwulusi only. The variations recorded in the presence of heavy metals in the different locations could be attributed to different activities going on in the locations.
Generally, soil heavy metal contamination was more than that of the vegetable. Mostly, soil physicochemical properties are responsible for plant metal uptake. Statistically, pH was significant in zinc. It has been established that heavy metal uptake by plants is pH dependent [43]. The pH of the location under study was slightly alkaline. Total nitrogen and cation exchange capacity were not significant in all the trace metals apart from in zinc. Contrary, total organic carbon and electrical conductivity were significant in all trace metals apart from in zinc. Bulk density was significant in chromium and zinc only. And the soil of the study area was sandy clay loam. All these factors have interactive effect on heavy metals uptake from soil.

4.2 Health risk assessment
The Target Hazard Quotient 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 [44]. THQ value greater than 1 showed that a population is at risk of metal contamination. The THQ of Cu, Cr, Cd, Zn, Pb and Fe were 0.111, 0.001, 0.432, 0.074, 0.413 and 0.477 respectively (Table 4.5). From the result, the risk exposure of the target population to heavy metal was in the order Fe > Cd > Pb > Cu > Zn > Cr. The THQ of all heavy metals in this study was less than 1; therefore, it does not call for health concern [25] did a similar work at Lagos and found out that Cd, Pb, Cu, Zn and Cr did not pose health concern to the inhabitants of the study area.

DIM refers to the quantity of metal taken by an individual per day. The DIM results in table 6, were compared with the tolerable daily intake for metals as recommended by WHO (1989) and Institute of Medicine (2001) [28]. It is obvious that the daily intake of Cu (0.393) and Zn (1.978) are lower than the recommended daily intake level of metals and the tolerable upper intake level (UL). But the DIM of Pb (0.128), Cd (0.038) and Fe (27.488) exceed the recommended daily intake level, however, fall within the tolerable upper level. Cr (0.127) is lower than the recommended oral reference dose (RfD) of 1.5mg/kg. However, the tolerable upper intake level for Cr has not been established. Since, the DIM of Pb, Cd and Fe are above the recommended daily intake, the inhabitants may be at risk of exposure to metals if the value increase above the UL. This result corroborates the work of [25].

The HRI of Cu, Cr, Cd, Zn, Pb and Fe were 9.825, 0.085, 38.000, 6.593, 36.570 and 42.289 respectively. Generally, HRI < 1 means that the exposed population is safe from metals health risk while HRI > 1 means the reverse [25, 45]. In this study, the HRI of the metals considered are greater than 1 except Cr. Therefore, the inhabitants may be at risk of Cu, Cd, Zn, Pb and Fe exposure [25, 44] also gave similar reports on Cu, Cd, Zn, Pb and Cr. Hazard index (HI) is used to evaluate the potential risk to human health when more than one heavy metal is involved. HI > 1 shows that a population is at risk. In this study, the HI
was 1.508. This showed that the population may be at risk of consuming this vegetable.

The analysis of trace metals in leafy vegetables is very important because of its toxicity. These findings collaborates the work of [30], who investigated heavy metals Fe, Cu, Zn, Cr, Cd and Pb content in vegetable and found out that all the trace metals were of varying concentrations in the vegetable, and were below the WHO/FAO safe limits. The findings also collaborate with the work of [25], who did a similar work in Lagos, Nigeria and found out that vegetables including fluted pumpkin accumulate Cu, Zn, Cr, Cd and Pb at varying concentrations. He also found out that the THQ value of all the metals were below the permissible limits and therefore, did not pose risk, but with continuous consumption of vegetables the values may increase.

5. Conclusion

All the trace metals studied were found in fluted pumpkin in varying concentrations. Although, the trace metals were below the WHO/FAO acceptable limits but they were all statistically significant. The result also showed that areas with high industrial and traffic activities recorded higher values of heavy metals contamination while residential areas recorded the least. The HRI and HI values showed that the inhabitants may be at risk of heavy metal contamination. The DIM value showed that Pb and Cd were below the UL but exceeded the recommended value.

References

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