Assessment of Heavy Metal Contents, and Probable Health Risks of Some Staple Vegetables in Enugu Metropolis

D. Ibegbu Madu¹*, A. Eze Anthonius¹, Atuadu Vivian², C. Ejiro Nonso¹ and E. Ezeagu Ikechukwu¹

¹Department of Medical Biochemistry, Faculty of Basic Medical Sciences, College of Medicine, University of Nigeria, Enugu Campus, Nigeria.
²Department of Anatomy, Enugu State University of Science and Technology, Enugu, Nigeria.

Authors’ contributions

This work was carried out in collaboration among all authors. Author EEI designed the study and wrote the protocol. Authors DIM and AEA managed the analyses of the study. Author DIM performed the statistical analysis, and wrote the first draft of the manuscript. Authors CEN and AV managed the literature searches. All authors read and approved the final manuscript.

Article Information

DOI: 10.9734/EJNFS/2021/v13i130341

Editor(s):
(1) Dr. Rasha Mousa Ahmed Mousa, University of Jeddah, Saudi Arabia.
(2) Hamid Sodaeizadeh, Natural Resources Yazd University, Iran.
(2) Tamara Myslyva, Belarusian State Agricultural Academy, Belarus.

Complete Peer review History: http://www.sdiarticle4.com/review-history/65143

Received 27 November 2020
Accepted 09 January 2021
Published 10 January 2021

Original Research Article

ABSTRACT

Heavy metals naturally are non-biodegradable constituents of the earth’s crust that accumulate and persist indefinitely in the ecosystem as a result of both human and natural activities. Their contamination of vegetables remains an issue of public health interest due to the frequency, and quantity of consumption. The overexposure to these heavy metals continues to pose serious health threat globally. This study was aimed to assess the heavy metal contents of staple vegetables [Telfairia occidentalis, Amaranthus hybridus and Ocimum gratissimum] within Enugu metropolis; the leaves were screened for heavy metals [Arsenic As, Lead Pb, Cadmium Cd, Nickel Ni, Chromium Cr and Cobalt Co], by atomic absorption spectroscopy (AAS). Results (Mean±SD, mgkg⁻¹) showed that Amaranthus hybridus: contained [Pb-0.109±0.350, Cr -0.161±0.004]; Ocimum gratissimum: [Ni-0.179±0.028, Cd-0.033±0.006, Cr-0.176±0.036], and Telfairia occidentalis: [Pb-0.153±0.139, Co-0.198±0.148]; of which some values were slightly above

*Corresponding author: Email: daniel.ibegbu@unn.edu.ng;
# Ibegbu MD-ORCID ID: https://orcid.org/0000-0002-1431-9624
WHO/FAO standards. Although, the estimated daily intakes (EDIs) were below referenced tolerable daily intakes (TDIs). The hazard quotients (HQs) were below 1 (HQ<1), but As and Cd, were exceptions; while the hazard index (HI) values were all above 1 (HI>1). The slightly above standard references of some of these heavy metals, and HI>1 values in this study are a concern, as potential health risks may arise amidst the population over a period of time, therefore, there is need to eliminate the likely sources of the latent contamination.

Keywords: Heavy metals; Telfairia occidentalis; Amaranthus hybridus; Ocimum gratissimum; health risk; Enugu.

1. INTRODUCTION

The benefits of vegetables as sources of foods cannot be overemphasized: they are important constituents of human diets [1], and can effectively buffer some toxic metabolites in the course of food digestion [2]. But possible association with toxicants -like heavy metals- is one issue that brings concerns about their enormous consumptions. Vegetables as food sources are consumed daily; therefore, could be a source of health risk when inadvertently contaminated by toxicants like heavy metals; which deleterious effects on exposure, only manifest after a prolonged period of time [3]. Heavy metals contamination of vegetables is mostly as a result of pollution of agricultural soil, which natural events such as weathering, erosion, atmospheric fall-out etc. are the known factors [4]. Also the activities of humans that include but not limited to irrigation with contaminated water, the addition of fertilizers and metal-based pesticides, industrial wastes-emissions and effluents. Other sources include during transportation, the harvesting process, storage and at the point of sale [5,6,7]. Heavy metals like Cd, Pb and As are non-biodegradable, therefore, their accumulation in human tissues could lead to progressive toxicity [8]. Pb, Cd and As are amongst the heavy metals that are mostly present in foods with highest toxic potential [9]. Studies have shown that some of these metals exceeded WHO recommended standards in leafy vegetables, for example, chromium in Telfairia occidentalis [10,11] and Nickel in Ocimum gratissimum [12]. Contamination of vegetables with heavy metals poses a great threat to human health and could result in a number of disease conditions; such as renal and neurological damages, developmental challenges in neonates, amongst others [13,14]. Food consumption is known to be one of the major pathways for human exposure to certain environmental contaminants [15], therefore, sources of food contaminants and measures to eliminate them are constantly a focus of research [16,17]. With the understanding of the potential health risks attributed to consumption of heavy metal contaminated vegetables, it is necessary to analyze these food items often, to ensure that their levels are not above acceptable set standards. There are many indigenous vegetables that are consumed in Enugu metropolis, which cultivation and trade are sources of livelihood for many that depend on subsistent or commercial agriculture; from which millions of Naira are generated annually. This study is necessary in this location also, because research has shown that soils around coal mines are contaminated with lots of heavy metals [18], the city is known for coal mining though the coal mining activities have long declined. Telfairia occidentalis, Amaranthus hybridus and Ocimum gratissimum are amongst the staple vegetables in Enugu, therefore are consumed every day by large percentage of the population, but very little is known about their heavy metal contents. The aim of this study was therefore to assess the levels of heavy metals content (As, Pb, Cd, Ni, Cr and Co) in staple vegetables (Telfairia occidentalis, (Cucubitaceae); Amaranthus hybridus (Amaranthaceae), and Ocimum gratissimum (Lamiaceae) sold in the Enugu markets and to determine their potentially harmful effects with calculating the hazard quotient for the child and adult population of the city.

2. MATERIALS AND METHODS

2.1 Study Area

Enugu is a cosmopolitan city known for coal mining; with sparse industrial sites while markets are common sights. It is situated in the southeast of Nigeria, and was the capital of the old eastern region of Nigeria. There are many water channels, several high and low lands across the city, with a population of about 722,664; a total area of 556 km² and is situated between the latitudes and longitudes of 6.4584°N, 7.5464°E, this city has a warm climate of average annual temperature of 26.3° C and rainfall of 1730mm. The map Fig. 1 [19] shows the area where the vegetables were purchased.
2.1 Sample collection and preparation

To assess the heavy metals [As, Pb, Cd, Ni, Cr and Co] content of staple vegetables within Enugu metropolis, three species - *Telfaira occidentalis*, *Amaranthus hybridus* and *Ocimum gratissimum* - were randomly purchased from different markets within the city during raining season; (a total of 12 samples each were purchased), three of which were bought at each market anytime the purchase was made, that lasted for a duration of 6 weeks. The leaves were clicked and used while the stems were discarded. The leaves were left in an open air in the laboratory for 24hrs before they were oven dried at 40°C for 10 hrs. with Gallenkamp oven. The crispy leaves were crushed, and similar amounts of each vegetable were screened for the heavy metals; using Buck model 205 atomic absorption spectroscopy (AAS). as described [20].

2.1.2 Hazard quotient determination and hazard index

\[
DIM (mgkg^{-1}Day^{-1}) = \frac{A(mgkg^{-1})xB(kg)}{C(kg)} \quad (Eqn...1)[21]
\]

Where DIM is Dietary intake of metal, A is concentration of the metal, B is ingestion rate, C is the average weight of individuals involved [child and adult taken to be 24 and 60 respectively] [21]; Vernonia amygdalina consumption rate in the study by Orisakwe et al. [21], equates to the consumption rate of the leafy vegetables in this study, therefore was used as a proportional injection rate for the vegetables in this study, which were 345 g day⁻¹ for adults, and 232 g day⁻¹ for children [21].

The hazard quotient (HQ) was determined as a ratio of daily intake of metal (DIM) to the oral reference dose for the heavy metal (USEPA 2010)

\[
\text{Hazard quotient} = \frac{\text{daily intake of metal}}{R_{fD}} \quad (Eqn...2)[22]
\]

Where: RfD is the oral reference dose for each heavy metal considered.

The hazard index (HI) was expressed as the total sum of the hazard quotients (HQs) of the heavy metals [23]

\[
\text{Hazard index} = HQ1 + HQ2 + HQ3 + \ldots + HQn \quad Eqn...3 \quad [23]
\]

2.2 Statistical Analysis

Data were analyzed with SPSS version 20. ANOVA was used to determine mean differences, and when significant (LSD) was
3. RESULTS AND DISCUSSION

This study presents results of levels of heavy metals - As, Pb, Cd, Co, Ni and Cr - assessed in different species of staple vegetables consumed in Enugu metropolis as purchased from different markets within the city. In order to determine possible contamination, this study results were considered to be of potential toxic effect when values were above set reference standards. The results showed that Pb ranged from 0.085 mgkg-1 in O. gratissimum to 0.153 mgkg-1 in T. occidentalis, As ranged from 0.046 mgkg-1 in T. occidentalis to 0.055 mgkg-1 in A. hybridus, Co ranged from 0.116 mgkg-1 in O. gratissimum to 0.198 mgkg-1 in T. occidentalis, Ni ranged from 0.161 mgkg-1 A. hybridus to 1.385 mgkg-1 in T. occidentalis, Cd ranged from 0.030 mgkg-1 in T. occidentalis to 0.033 mgkg-1 in O. gratissimum, and Cr ranged from 0.135 mgkg-1 in T. occidentalis to 0.176 mgkg-1 in O. gratissimum in Table 1. The amounts of Ni and Cr were higher in A. hybridus followed by Co, and least was in Cd. Cd was highest in O. gratissimum followed by Ni, and As had the least while in T. occidentalis Ni was highest followed by Co and the least was Cd. The thresholds Table 2 for heavy metals in leafy vegetables were exceeded in some vegetables in this study. As threshold of the 0.5 mgkg-1 was slightly exceeded in A. hybridus and O. gratissimum. Pb was higher than 0.1 mgkg-1 threshold in T. occidentalis and A. hybridus. Cd was higher than prescribed threshold of 0.03 mgkg-1 in O. gratissimum, while Ni exceeded the 0.3 mgkg-1 permissible concentration in T. occidentalis Table 1.

There were no statistically significant differences between the heavy metal contents in A. hybridus compared to O. gratissimum (p<0.05), comparison of heavy metal contents in A. hybridus and T. occidentalis showed statistically significant differences in As and Ni contents (p<0.05), while O. gratissimum and T. occidentalis comparison showed statistically significant differences in Ni and Cr (p<0.05) Table 3. The heavy metal concentrations in the vegetables [O. gratissimum (O.g); A. hybridus (A.h); T. occidentalis (T.o)] varied as follows Pb: T.o>A.h>O.g; Co: T.o>A.h>O.g; As: A.h>O.g>T.o; Ni: T.o>O.g>A.h; Cr: O.g>A.h>T.o, Cd: O.g>A.h>T.o Figs: 2,3 & 4.

Table 1. Statistical characteristics of the of heavy metals content in the vegetables (mg/kg) [n =12]

| Heavy metal | Heavy metal content value (mg/kg) | Sd | Cv % | Med | Kurtosis | Skewness |
|-------------|----------------------------------|----|------|-----|----------|----------|
|              | min | max | mid |     |          |          |
| **Amaranthus hybridus** | | | | | | |
| Pb           | 0.071 | 0.194 | 0.133 | 0.035 | 32.00 | 0.108 | 2.163 | 0.637 |
| As           | 0.042 | 0.070 | 0.056 | 0.009 | 1.60 | 0.055 | -0.489 | 0.188 |
| Co           | 0.093 | 0.518 | 0.306 | 0.119 | 83.50 | 0.110 | 11.796 | 3.423 |
| Ni           | 0.105 | 0.212 | 0.159 | 0.036 | 22.30 | 0.161 | -1.412 | -0.064 |
| Cd           | 0.020 | 0.043 | 0.032 | 0.009 | 25.80 | 0.031 | -1.564 | -0.062 |
| Cr           | 0.078 | 0.215 | 0.147 | 0.045 | 27.70 | 0.169 | -0.382 | -0.716 |
| **Ocimum gratissimum** | | | | | | |
| Pb           | 0.069 | 0.131 | 0.100 | 0.018 | 21.50 | 0.078 | 2.996 | 1.795 |
| As           | 0.0435 | 0.063 | 0.053 | 0.006 | 11.60 | 0.051 | -0.153 | 0.441 |
| Co           | 0.100 | 0.133 | 0.117 | 0.009 | 8.00 | 0.119 | 0.204 | -0.462 |
| Ni           | 0.135 | 0.221 | 0.178 | 0.029 | 15.90 | 0.181 | -1.118 | -0.183 |
| Cd           | 0.022 | 0.044 | 0.033 | 0.007 | 18.18 | 0.033 | -0.735 | -0.051 |
| Cr           | 0.110 | 0.220 | 0.165 | 0.036 | 20.50 | 0.189 | -0.755 | -0.764 |
| **Telfaria occidentalis** | | | | | | |
| Pb           | 0.081 | 0.590 | 0.336 | 0.139 | 90.84 | 0.119 | 11.540 | 3.370 |
| As           | 0.030 | 0.060 | 0.045 | 0.008 | 17.30 | 0.046 | 0.708 | -0.414 |
| Co           | 0.107 | 0.647 | 0.377 | 0.148 | 74.75 | 0.145 | 9.468 | 2.967 |
| Ni           | 0.149 | 2.275 | 1.212 | 0.712 | 51.40 | 1.378 | -0.398 | -0.650 |
| Cd           | 0.019 | 0.037 | 0.028 | 0.006 | 23.08 | 0.026 | -0.810 | 0.422 |
| Cr           | 0.101 | 0.203 | 0.152 | 0.025 | 18.70 | 0.132 | 4.641 | 1.775 |

Note: Sd is the standard deviation; Cv is the coefficient of variation; Med is the median
Table 2. Standard references of permissible levels of heavy metals for vegetables

| Heavy metal | NEPA-China a | FAO/WHO (CODEX)b, c | Thresholdd | Recommended Max. limit |
|------------|--------------|----------------------|------------|------------------------|
| Pb         | 0.2          | 0.5(2001)            | 0.2        | 0.3                    |
| As         | 0.5          | 0.2(2015), 0.1(2011)d | -          | 0.43                   |
| Co         | -            | 0.5                  |            | 50                     |
| Ni         | 0.3          | 10(2011)d            | 2          | 67.9                   |
| Cd         | 0.05         | 0.02(2001)           | 0.05       | 0.2                    |
| Cr         | 0.5          | 2-3(2011)d           | 0.5        | 2.3                    |

a National Environmental Protection Agency-China (NEPA-China) 2001 [24], b Food and Agriculture Organization (FAO), 2001 [25], c Food and Agriculture Organization (FAO) 2015 [26], d Itanna 2002 [27], e Shaheen et al. 2016 [28], f Murtaza et al. 2008 [29], g Hu et al. [30].

Co, Pb and Ni values were highest in T. occidentalis Figs. 2&3; Cr and Cd in O. gratissimium Fig. 4 while As in A. hybridus Fig. 3. T. occidentalis may have been cultivated in an area contaminated with the heavy metals; alternatively fertilizers application could be a source of the slightly above normal referenced values in the vegetables as observed in this study. Also there could be a possibility that some of these vegetables could have been grown along sewage sites or poor water effluents from domestic activities by those that live in the suburb of the city, thereby contaminating them with these metals, also Enugu seats on coal, though mining activities have long declined but its effects may still be affecting crop production, as it has been reported that soils around coal mines are contaminated with many heavy metals [18].

Some research findings on heavy metal evaluation of these vegetables in other places where they are also cultivated and consumed have been documented. Evaluation of T. occidentalis in some studies has showed that Cd and Cr concentrations of 0.55 mgkg-1 and 1.4 mgkg-1 respectively were reported by Njoku-Tony et al. [31] in Rivers state, while Egwu et al. [11] reported Cd and Cr of 0.14 mgkg-1 and 0.71 mgkg-1 respectively in Niger state. Cd and Cr values in this study were lower Table 1 than those reported from studies in Niger sate and Rivers state.  

Okereke et al. [32] findings showed that Ni of 0.12 mgkg-1 and 2.7 mgkg-1 were found in a similar study in Ebonyi and Rivers respectively, while that of Ebonyi state was lower than the concentration found in this study (Table 1), the value of the study in Rivers state was higher. Co of 1.75 mgkg-1 and 0.14 mgkg-1 were reported by Kalagbor et al. [33] and Ukpari et al. [34] respectively in Rivers state. Egwu et al. [11] reported Pb value of 4.27 mgkg-1 in Niger state while Nwoko et al. [35] showed in their study that the vegetable contained 0.727 mgkg-1 in Imo state, both of which were higher than our findings. As of 0.42 mgkg-1 was reported by Uka et al. [36] in Ebonyi state while Adepoju-Bello et al. [37] showed that the vegetable in their study contained 1.183 ug/g in Lagos, which is lower than the value obtained in our study.

In Ocimum gratissimium, Cd of 0.08 mgkg-1 was found in the vegetable collected around residential area in Lagos [38], Vaikosen and Alade [39] reported a concentration of 0.41 mgkg-1 in Bayelsa, while Adedokun et al. [40] reported a value of 0.20 mgkg-1 in Lagos. Cr of 1.68 mgkg-1 was reported by Abdurahman et al. [41] in Borno state, while Patrick-Iwuanyanwu and Chioma [12] reported a value of 1.369 mgkg-1 in Bayelsa state. Ni of 3.625 mgkg-1 and 0.093 mgkg-1 in two different locations in Bayelsa state were also reported by Patrick-Iwuanyanwu and Chioma, [12], and in Abuja Ojo et al. [38] showed that the vegetable contained Ni of 1.08 mgkg-1 in residential area. Co of 3.5 mgkg-1 was reported by Kalagbor et al. [33] in Rivers state. Alexander [42] reported a Pb concentration of 0.005 mgkg-1 in Adamawa, but Kalagbor et al. [33] reported 6.25 mgkg-1 in Rivers while in Lagos Adedokun et al. [40] reported a range of 9.34 mgkg-1 to 5.44 mgkg-1. In Ghana, Annan et al. [43] reported As of <0.001 ugg⁻¹, this is lower than the value found in our study Table 1. The concentration of Cd found in O.gratissimium in this study was higher than that found in the vegetable in Lagos, but lower than that found in the vegetable in Bayelsa state. Also the value found in our study was higher than that found in Adamawa state but lower than that found in Lagos and Rivers states, this may not be unexpected as Lagos is a great commercial city and Rivers a crude oil exploration state.
Ibegbu et al.; EJNFS, 13(1): 1-14, 2021; Article no.EJNFS.65143

Fig. 2. Comparison of heavy metal contents of the vegetables- cobalt: lead

Table 3. p-values of post ANOVA tests of comparisons of the heavy metals content of the vegetables

| Heavy metal | Amaranthus hybridus/ Ocimum gratissimum | Amaranthus hybridus/Telfairia occidentalis | Ocimum gratissimum Telfairia occidentalis |
|-------------|----------------------------------------|------------------------------------------|------------------------------------------|
| Pb          | 0.767                                  | 0.452                                    | 0.149                                    |
| As          | 0.491                                  | 0.024*                                   | 0.255                                    |
| Co          | 0.846                                  | 0.473                                    | 0.207                                    |
| Ni          | 0.993                                  | 0.001*                                   | 0.001*                                   |
| Cd          | 0.993                                  | 0.113                                    | 0.090                                    |
| Cr          | 0.629                                  | 0.233                                    | 0.036*                                   |

*Value is significant at P<0.05 when each vegetable’s heavy metals was compared one to another
Fig. 3. Comparison of heavy metal contents of the vegetables—arsenic: nickel

Table 4. Estimated daily intake of *Amaranthus hybridus*, *Ocimum gratissimum* and *Teliferia occidentalis*

| Heavy metal  | *A. hybridus* (mg kg⁻¹ dry wt.) | EDI in A | EDI in C | *O. gratissimum* (mg kg⁻¹) | EDI in A | EDI in C | *T. occidentalis* (mg kg⁻¹) | EDI in A | EDI in C |
|--------------|---------------------------------|----------|----------|-----------------------------|----------|----------|-----------------------------|----------|----------|
| Lead         | 0.109                           | 6.27E-04 | 1.05E-03 | 0.085                       | 4.89E-04 | 8.22E-04 | 0.153                       | 8.80E-04 | 1.48E-03 |
| Arsenic      | 0.055                           | 3.16E-04 | 5.32E-04 | 0.051                       | 2.93E-04 | 4.93E-04 | 0.046                       | 2.65E-04 | 4.45E-04 |
| Cobalt       | 0.142                           | 8.17E-04 | 1.37E-03 | 0.116                       | 6.67E-04 | 1.12E-03 | 0.198                       | 1.14E-03 | 1.19E-03 |
| Nickel       | 0.161                           | 9.26E-04 | 1.56E-03 | 0.179                       | 1.03E-03 | 1.73E-03 | 1.385                       | 7.96E-03 | 1.34E-02 |
| Cadmium      | 0.032                           | 1.84E-04 | 3.09E-04 | 0.033                       | 1.90E-04 | 3.19E-04 | 0.026                       | 1.50E-04 | 2.51E-04 |
| Chromium     | 0.161                           | 9.26E-04 | 1.56E-03 | 0.176                       | 1.01E-03 | 1.70E-03 | 0.135                       | 7.76E-04 | 1.31E-03 |

EDI=Estimated Daily intake, A=Adults, C=Children
Fig. 4. Comparison of heavy metal contents of the vegetables - Chromium: Cadmium

Table 5. Hazard quotient (HQ) and hazard index (HI) of *A. hybridus*, *O. gratissimum* and *T. occidentalis* (Adults and Children)

| Metals | RFd | A.h(A) | A.h(C) | O.g(A) | O.g(C) | T.o(A) | T.o(C) |
|--------|-----|--------|--------|--------|--------|--------|--------|
| Lead   | 0.0035 | 1.79E-01 | 3.00E-01 | 1.40E-01 | 2.35E-01 | 2.51E-01 | 4.23E-01 |
| Arsenic| 0.0003 | 1.05E+00 | 1.77E+00 | 9.77E-01 | 1.64E+00 | 8.83E-01 | 1.48E+00 |
| Cobalt | 0.02   | 4.09E-02 | 6.85E-02 | 3.34E-02 | 5.60E-02 | 5.70E-02 | 9.55E-02 |
| Nickel | *0.02* | 4.63E-02 | 7.80E-02 | 5.15E-02 | 8.65E-02 | 3.98E-01 | 6.70E-01 |
| Cadmium| 0.001  | 1.84E-01 | 3.09E-01 | 1.90E-01 | 3.20E-01 | 1.50E-01 | 2.50E-01 |
| Chromium| 0.003 | 3.09E-01 | 5.20E-01 | 3.37E-01 | 5.67E-01 | 2.59E-01 | 4.37E-01 |
| HI     | 1.81E+00 | 3.05E+00 | 5.14E+00 | 8.64E+00 | 3.95E+00 | 6.63E+00 |        |

RFd= Oral reference dose [66] [67]; A.h=A. hybridus; O.g=O. gratissimum; T.o=T. occidentalis; A= Adults; C= Childr
In some evaluation studies with A. hybridus, Gbaye et al. [44] reported Cd range of 0.03 - 0.06 mgkg-1 in Ondo state, Ogoko [45] reported 0.48 mgkg-1 in a study in Abia state while in Kaduna, Akubugwo et al. [46] reported a Cd range of 0.04-1.19 mgkg-1 . Izah and Aigberua [47] reported Cr value of 8.08 mgkg-1 in their study. Ogoko [45] reported Pb of 4.43 mgkg-1 in Abia state while Gbaye et al. [44] reported 0.07 mgkg-1 of Pd also in Ondo state. Ni of 0.29 mgkg-1 and As of 0.08 mgkg-1 were found in the vegetable in a similar study in Abia state [45], and in Burkina Faso, Bakary et al. [48] reported 0.145 mgkg-1 of As in the vegetable, Oyelola and Banjoko (2015) showed that the vegetable contained Co of 0.52 mg/100 g in a study in Lagos, while Ani et al. [49] also, reported a Co of 0.042 mgkg-1 in Mgbowo, Enugu. In another related study, Oladeji and Saeed 2015 [50] found that the vegetable contained a Co ranged 6.25-8.45 mgkg-1 in Kaduna state. The reported values of heavy metal in A. hybridus elsewhere were higher than values found in our study Table 1, an indication that level of the vegetable contamination in our study area was minimal compared to other regions. Clearly, reports from other places suggest differences in the concentrations of these heavy metals in the vegetables; this disparity could largely be due to environmental, cultural and industrial factors.

Generally, heavy metals can cause severe problems for humans, for example, exposure to high concentration of Pb has been shown to cause a number of deleterious human conditions like brain injury, damages to nervous system, red blood cells; and renal system; induces low IQ and impairs development, causes loss of memory, nausea, insomnia, anorexia, weakness of the joints and reduces fertility [51]. Cadmium has toxic effects on the kidneys as well as the skeletal and respiratory systems [52] and has also been classified as a human carcinogen [53]. High intake of cadmium on the other hand can lead to disturbances in calcium metabolism, and may contribute to smoking-related lung disease [53,54,55]. Allergic reactions are the most common harmful health effect of nickel, which mostly occur through skin contact that could result in chronic bronchitis, reduced lung function, and cancer of the lung, and nasal sinus [56]. The harmful effect of long-term exposure to high levels of inorganic arsenic is usually observed in the skin, which includes pigmentation changes, skin lesions and hard patches on the palms and soles of the feet (hyperkeratosis) that can be as a result of acute or chronic exposure [57]. Other deleterious health effects associated with long-term ingestion of inorganic arsenic include developmental effects, diabetes, pulmonary disease, and cardiovascular disease [57]. Arsenic exposure has also been related with adverse pregnancy outcomes and infant mortality, also with impacts on child health [58], and exposure in utero and in early childhood has been linked to increases in mortality in young adults due to multiple cancers, lung disease, heart attacks, and kidney failure [59]. Cobalt has both beneficial and harmful effects on human health; this is beneficial because it is a component of vitamin B12, Its concentration of 0.16–1.0 mgkg-1 body weight has been found useful in treatment of anaemia. It also increases red blood cell production in healthy individuals, but only at very high exposure levels [60]; it can also enhance the kinetics of some enzymes, such as heme oxidase in the liver [61]. Excessive exposure to cobalt however, can lead to harmful health effects such as difficulty in breathing, and serious side effects on the lungs, including asthma, pneumonia, and wheezing, this also interferes with and depresses iodine metabolism, resulting in reduced thyroid activity [60,61]. Chromium is an essential nutrient required by the human body to promote the action of insulin for the sugars, proteins and fats utilization [62,63]. But high doses of chromium over a long period of time can give rise to various cytotoxic and genotoxic reactions that can affect the immune system [62]. Occupational exposure to Cr(VI) compounds in a number of industries has been associated with increased risk of respiratory system cancers [64].

Health risk assessment was carried out to evaluate the possible association of the vegetables consumption to the wellbeing of the study population. The EDIs of the heavy metals as a result of the consumption of the vegetables are as presented Table 4. The EDI ranged from 4.89E-04 in O. gratissimum [adults] to 1.12E-03 in T. occidentalis [children]. All the EDIs were below the TDI [65], an indication that the individual consumption of the vegetables may present no health risks amongst the population.

The HQs of all the heavy metals in this study were less than 1 (HQ<1), with exception of As and Cd (Table 5). HQ values less than 1 (HQ<1) indicates that the cumulative consumption of that substance will not induce an adverse effect but with tendency of adverse effect when it is above 1 (HQ>1); the same applies also to H. HQ of As in all the three (3) vegetables ranged from 9.77E-
01 to 1.77E+00, and were above 1 in all, except in O. gratissimum [children] Table 5; also HQs of Cd in O. gratissimum in adults and children were 1.87E+00 and 3.15E+00 respectively with values above 1 (HQ>1) (Table 5) The HI of the heavy metals in each vegetable were above 1(HI>1); also the HIs of all the heavy metals in the three (3) vegetables were above 1, which ranged from 1.81E+00 in A. hybridus [adults] to 5.74E+00 in O. gratissimum [children] Table 5, which presents a tendency of deleterious side effect.

Since source of food contaminants and measures to eliminate them had been described as a constant focus of research [16,17], also considering the high HI of the heavy metals in the vegetables in our study, there is therefore, the need for a review of the vegetables for these heavy metals from time to time to checkmate a possible chronic heavy metal toxicity amongst the population.

4. CONCLUSION

Our findings showed that some of the heavy metals like Pb and Cr, were slightly above the FAO/WHO set standard references, and all the determined heavy metals’ HIs in all the vegetables were above 1 (HI>1), there is then the need to trace and curb the latent source of contamination of the vegetables to avoid the adverse implications of heavy metals to healthy living of the population.

Declaration of interest: we have no conflict of interest to declare

5. FUNDING

This study received no funding.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

REFERENCES

1. World Health Organization, Food and Agriculture Organization of the United Nations. Fruit and Vegetables for Health. Report of a Joint FAO/WHO Workshop, 1–3 September 2004, Kobe, Japan; 2005.
2. Yang QW, Xu Y, Liu SJ, He JF, Long FY. Concentration and potential health risk of heavy metals in market vegetables in Chongqing, China. Ecotox Environ Saf. 2011;74(6):1664-1669.
3. Huang SS, Liao QL, Hua M, Wu XM, Bi KS, Yan CY. Survey of heavy metal pollution and assessment of agricultural soil in Yangzhong district, Jiangsu Province, China. Chemosph. 2007;67(11): 2148-2155.
4. Rai PK, Lee SS, Zhang M, Tsang YF, Kim KH. Heavy metals in food crops: Health risks, fate, mechanisms, and management. Environment international. 2019;125:365-385.
5. Marcovecchio JE, Botté SE, Freije RH. Heavy metals, major metals, trace elements. Handbook of water analysis. 2007;2:275-311.
6. Wuana RA, Okieimen FE. Heavy metals in contaminated soils: a review of sources, chemistry, risks and best available strategies for remediation. Isrn Ecol; 2011.
7. Masindi V, Muedi KL. Environmental contamination by heavy metals. Heavy Met. 2018;10:115-132.
8. Alam MGM, Snow ET, Tanaka A. Arsenic and heavy metal contamination of vegetables grown in Samta village, Bangladesh. Sci Tlt Environ. 2003;308(1-3):83-96.
9. Radwan MA, Salama AK. Market basket survey for some heavy metals in Egyptian fruits and vegetables. Food and Chemical Toxicology. 2006;44(8):1273-1278.
10. Enemugwem RI, Baridagarac SC, Mlkue-Yobe TFB, Godwin C, Sunday, Atta J. Heavy metal levels in fluted pumpkin leaves (Telfairia occidentalis) obtained from Tai express way (Tai LGA) and Bori market (Khana Lga) in Ogoni land, Rivers State, Nigeria. International Journal of Scientific and Engineering Research. 2016;7(11):416. ISSN 2229-5518.
11. Egwu O, Casmir U, Victor U, Samuel U, Dickson M, Oluwaniola O. Evaluation and ecological risk assessment of selected heavy metal pollution of soils and Amaranthus cruentus and Telfairia occidentalis Grown Around Dump Site in Chanchaga Minna, Niger State, Nigeria. Asian Journal of Environment & Ecology. 2019;10(2):1-16. Available:https://doi.org/10.9734/ajee/2019/v10i230114
12. Patrick-Iwuanyanwu K, Chioma NC. Evaluation of heavy metals content and human Health risk assessment via consumption of vegetables from selected markets in Bayelsa State, Nigeria. Biochem Anal Biochem. 2017;6:332. DOI: 10.4172/2161-1009.1000332

13. WHO (World Health Organization). Cadmium. Environmental Health Criteria, Geneva. 1992;134.

14. Okonkwo MA, Onyechi UA, Anukwuorji CA, Chukwunwe PC, Sopuru JC. Heavy metal contamination of selected vegetables from crude oil and non crude oil-producing states in Nigeria: A comparative study, Sustainable Food Production. 2018;3:1-15. ISSN:2624-876X. DOI:10.18052/www.sci_press.com/SFP.3.1

15. Fries GF. A review of the significance of animal food products as potential pathways of human exposures to dioxins. J An Sci. 1995;73(6):1639–1650.

16. Barnaby R, Liefeld A, Jackson BP, Hampton TH, Stanton BA. Effectiveness of table top water pitcher filters to remove arsenic from drinking water. Environ. Res. 2017;158:810–815.

17. Wongkasuluk P, Chotpantarat S, Siriwong W, Robson M. Heavy metal contamination and human health risk assessment in drinking water from shallow groundwater wells in an agricultural area in Ubon Ratchathani province, Thailand. Environ Geochem Hlth. 2013;36:169–182.

18. EzemokeWE, Ichu CB, Okoro JN, Opara AI. Evaluation of heavy metal contamination of soils along Awka-Enugu road, Southeastern Nigeria. As J Environ Ecol. 2017;4(1): 1-11.

19. Ubachukwu NN, Phil-Eze PO, Emeribe CN. Analysis of household hazardous wastes awareness level in Enugu metropolis. Academic Journal of Interdisciplinary Studies. 2014;3(1):369.

20. Oluremi OI, Solomon AO, Saheed AA, Fatty acids, metal composition and physico-chemical parameters of Igbemo Ekiti rice bran oil. Journal of Environmental Chemistry and Ecotoxicology. 2013;5(3):39-46.

21. Orisakwe OE, Ozoani HA, Nwaogozie IL, Ezeijiofor AN. Probabilistic health risk assessment of heavy metals in honey, *Manihot esculenta*, and *Vernonia amygdalina* consumed in Enugu State, Nigeria. Environ Monit Assess. 2019;191(7):424.

22. USEPA (US Environmental Protection Agency), Exposure Factors Handbook General Factors. EPA/600/P-95/002Fa, vol. I. Office of Research and Development, National Center for Environmental Assessment, US Environmental Protection Agency. Washington, DC; 2010.

23. USEPA (US Environmental Protection Agency). Risk assessment guidance for superfund. Human Health Evaluation Manual Part A, Interim Final, vol. I. Washington (DC), United States Environmental Protection Agency; EPA/540/1-89/002; 1989.

24. National Environmental Protection Agency of China. Safety quality standard for non-environmental pollution vegetable (GB/T 18407.1–2001); 2001.

25. Food and Agriculture Organization (FAO). Codex alimentarius commission food additives and contaminants. FAO/WHO, Rome, Italy. ALINORM 01/12A. 2001;1:289.

26. Food and Agriculture Organization (FAO). 2015 General Standard for Contaminants and Toxins in Food and Feed (Codex Stan 193-1995); 2015. www.fao.org › download › standards › CXS_193e_2015

27. Itanna F. Metals in leafy vegetables grown in addis ababa and toxicological implications. Ethiop J Hlth Dev. 2002;16(3):295-302.

28. Shaheen N, Irfan NM, Khan IN, Islam S, Islam MS, Ahmed MK. Presence of heavy metals in fruits and vegetables: health risk implications in Bangladesh. Chemosph. 2016;152:431-438.

29. Murtaza G, Ghafoor A, Qadir M. Accumulation and implications of cadmium, cobalt and manganese in soils and vegetables irrigated with city effluent. J Sci Food Agric. 2008;88(1):100-107.

30. Hu J, Wu F, Wu S, Cao Z, Lin X, Wong MH. Bioaccessibility, dietary exposure and human risk assessment of heavy metals from market vegetables in Hong Kong revealed with an in vitro gastrointestinal model. Chemosph. 2013;91(4):455-461.

31. Njoku-Tony RF, Udofia HS, Nwoko CO, Ihejirika CE, Ebe TE, Egbuawa IO. Heavy metal concentration level in fluted pumpkin

32. Ezejiofor C, Chemistry. Ekiti metropolis. waste CN. Ecol. AI. Ezemokwe Geochem Ratchathani wells drinking and arsenic table Hampton Barnaby An pathways animal oil vegetables metal CA, Okonkwo Geneva. Cadmium. DOI: Biochem consumption human Patrick Sci. Robson 1995;91(4):455-461. Human Health Food R, human 2017;610–847. dissolved heavy metals contamination in drinking water from shallow groundwater wells in an agricultural area in Ubon Ratchathani province, Thailand. Environ Geochem Hlth. 2013;36:169–182. EzemokeWE, Ichu CB, Okoro JN, Opara AI. Evaluation of heavy metal contamination of soils along Awka-Enugu road, Southeastern Nigeria. As J Environ Ecol. 2017;4(1): 1-11. Ubachukwu NN, Phil-Eze PO, Emeribe CN. Analysis of household hazardous wastes awareness level in Enugu metropolis. Academic Journal of Interdisciplinary Studies. 2014;3(1):369. Oluremi OI, Solomon AO, Saheed AA, Fatty acids, metal composition and physico-chemical parameters of Igbemo Ekiti rice bran oil. Journal of Environmental Chemistry and Ecotoxicology. 2013;5(3):39-46. Orisakwe OE, Ozoani HA, Nwaogozie IL, Ezeijiofor AN. Probabilistic health risk assessment of heavy metals in honey, *Manihot esculenta*, and *Vernonia amygdalina* consumed in Enugu State, Nigeria. Environ Monit Assess. 2019;191(7):424. USEPA (US Environmental Protection Agency), Exposure Factors Handbook General Factors. EPA/600/P-95/002Fa, vol. I. Office of Research and Development, National Center for Environmental Assessment, US Environmental Protection Agency. Washington, DC; 2010. USEPA (US Environmental Protection Agency). Risk assessment guidance for superfund. Human Health Evaluation Manual Part A, Interim Final, vol. I. Washington (DC), United States Environmental Protection Agency; EPA/540/1-89/002; 1989. National Environmental Protection Agency of China. Safety quality standard for non-environmental pollution vegetable (GB/T 18407.1–2001); 2001. Food and Agriculture Organization (FAO). Codex alimentarius commission food additives and contaminants. FAO/WHO, Rome, Italy. ALINORM 01/12A. 2001;1:289. Food and Agriculture Organization (FAO). 2015 General Standard for Contaminants and Toxins in Food and Feed (Codex Stan 193-1995); 2015. www.fao.org › download › standards › CXS_193e_2015 Itanna F. Metals in leafy vegetables grown in addis ababa and toxicological implications. Ethiop J Hlth Dev. 2002;16(3):295-302. Shaheen N, Irfan NM, Khan IN, Islam S, Islam MS, Ahmed MK. Presence of heavy metals in fruits and vegetables: health risk implications in Bangladesh. Chemosph. 2016;152:431-438. Murtaza G, Ghafoor A, Qadir M. Accumulation and implications of cadmium, cobalt and manganese in soils and vegetables irrigated with city effluent. J Sci Food Agric. 2008;88(1):100-107. Hu J, Wu F, Wu S, Cao Z, Lin X, Wong MH. Bioaccessibility, dietary exposure and human risk assessment of heavy metals from market vegetables in Hong Kong revealed with an in vitro gastrointestinal model. Chemosph. 2013;91(4):455-461. Njoku-Tony RF, Udofia HS, Nwoko CO, Ihejirika CE, Ebe TE, Egbuawa IO. Heavy metal concentration level in fluted pumpkin
(Telfairia occidentalis) grown around obio/akpor, Rivers State, Nigeria: Its Health Implications. J Environ Sci Pub Hlth. 2020;4:16-31.

32. Okereke CJ, Essien EB, Wegwu MO. Human health risk assessment of heavy metal contamination for population via consumption of selected vegetables and tubers grown in farmlands in rivers state, South-South Nigeria. J Anal Pharm Res. 2016;3(6):00077.

33. Kalagbor IA, Barisere V, Barivule G, Barile S, Bassey C. Investigation of the presence of some heavy metals in four edible vegetables, bitter leaf (Vernonia amygdalina), scent leaf (Ocimum gratissimum), water leaf (Talinum triangulare) and fluted pumpkin (Telfairia occidentalis) from a Cottage Farm in Port Harcourt. Res J Environ Eth Sci. 2014,6(1):18-24.

34. Ukpabi C, Akubugwo EI, Agbafor K, Wogu C, Chukwu HC. Phytochemical and heavy metal composition of Telfairia occidentalis and Talinum triangulare grown in Aba Nigeria and environmental health implications. Am J Biochem p-ISSN: 2163-3010 e-ISSN: 2163-3029. 2013;3(3):67-73.

35. Nwoko CO, Emenyonu EN, Umejuru CE. Trace metal contamination of selected vegetables grown around owerrri municipality, Nigeria. J Agri Ecol Res Inter. 2014;1(1):18-29.

36. Uka UN, Chukwuka KS, Afoke C. Heavy metal accumulation by Telfairia occidentalis Hook f. grown on waste dumpsites in South-Eastern Nigeria. Res J Environ Toxicol. 2013;7:47-53.

37. Adepoju-Bello AA, Okeke CP, Bamgbade I, Oguntibeju OO. Determination of the concentration of selected heavy metals in indigenous plant: Telfairia occidentalis. Clon Transgen. 2013;2:112.

38. Ojo FO, Tukura BW, Madu PC. Comparative analysis of heavy metal content in soil and their transfer to Ocimum gratissimum and Moringa oleifera vegetables planted in farms by bmuko quarry sites. Chem Res J. 2018;3(4):206-225.

39. Valkosen EN, Alade GO. Determination of heavy metals in medicinal plants from the wild and cultivated garden in Wilberforce Island, Niger Delta region, Nigeria. J Pharm Pharmac Res. 2017;5(2):129-143.

40. Adedokun AH, Njoku Kelechi L, Akinola MO, Adesuyi AA, Jolaoso AO. Potential human health risk assessment of heavy metals intake via consumption of some leafy vegetables obtained from four market in lagos metropolis, Nigeria. J Appl Sci Environ Mangt. 2016;20(3):530-539.

41. Abdurahman FI, Tijiani MA, Osuji UO. Proximate content and chemical composition of Ocimum viridis leaf and Ocimum gratissimus leaf. Inter Res J Pharm. 2012;3(4):153-156.

42. Alexander P. Phytochemical screening and mineral composition of the leaves of Ocimum gratissimum (scent leaf). Int J Appl Sci Biotech. 2016;4(2):161-165.

43. Annan K, Dickson RA, Amponsah IK, Nooni IK. The heavy metal contents of some selected medicinal plants sampled from different geographical locations. Pharmac Res. 2013;5(2):103–108.

44. Gbaye OA, Olalowo OO, Ologundudu F. Bioaccumulation potential of heavy metals in leaves of Amaranthus hybridus L. and Telfaria occidentalis Hook. f. from selected vegetable farms within Akure metropolis; 2018. Accessed November, 2020. Available:https://zenodo.org/record/1446497

45. Ogoko EC. Phytochemical and heavy metal analysis of Gongronema latifolium, Talinum triangulare and Amaranthus hybridus. FUW Tren Sci Techn J. 2018;3(1):195 – 200.

46. Akubugwo EI, Obasi A, Chinyere GC, Eze E, Nwokeoji O, Ugboogu EA. Phytoaccumulaion effects of Amaranthus hybridus L grown on buwaya refuse dumpsites in Chikun, Nigeria on heavy metals. J Biodiver Environ. 2012;2(5):10-17.

47. Izah SC, Aigberua AO. Comparative assessment of selected heavy metals in some common edible vegetables sold in Yenagoa metropolis, Nigeria. J Biotech Res. 2017;3(8):66-71.

48. Bakary T, Guira F, Sourabié PB, Zongo O, Tapsoba F, Zongo C. Evaluation of heavy metals and pesticides contents in market-gardening products sold in some principal markets of Ouagadougou (Burkina Faso). J Micro Biotech F Sci. 2019;8(4):1026-1034.
49. Ani ON, Achikanu CE, Udeh JO. Analysis of minerals and heavy metals content in traditional vegetables in South Eastern Nigeria. J Environ Sci, Toxicol F Tech. 2019;139(12):01-05.

50. Oladeji SO, Saeed MD. Assessment of cobalt levels in wastewater, soil and vegetable samples grown along Kubanni stream channels in Zaria, Kaduna State, Nigeria. Afr J Environ Sci Tech.. 2015;9(10):765-772.

51. Ogwu CE, Ubani CS, Osuji CA, Ugwu CV. Heavy metal risk assessment on the consumption of Talinum triangulare grown on sewage dump site in university of Nigeria, Nsukka. J Res Environ Sci Toxicol. 2019;8(2):104-112.

52. WHO (World Health Organization). Preventing disease through healthy environments exposure to cadmium: a major public health concern. Department of Public Health, Environmental and Social Determinants of Health World Health Organization 20 Avenue Appia, 1211 Geneva 27, Switzerland; 2019. Available:https://apps.who.int/iris/bitstream/handle/10665/329480/WHO-CED-PHE-EPE-19.4.3-eng.pdf?ua=1

53. IARC (The International Agency for Research on Cancer) Nickel and nickel compounds. IARC Monogr. Eval. Carcinog. Risk Hum. 2012;100C:169–218. Available:https://monographs.iarc.fr/wp-content/uploads/2018/06/mono100C-10.pdf

54. IARC Summaries & evaluations: Cadmium and cadmium compounds (Group 1). Lyon, International Agency for Research on Cancer, p. 119 (IARC Monographs on the Evaluation of Carcinogenic Risks to Humans. 1993;58. Available:https://monographs.iarc.fr/wp-content/uploads/2018/06/mono100C-8.pdf

55. IPCS. Cadmium, cadmium chloride, cadmium oxide, cadmium sulphide, cadmium acetate, cadmium sulphate. Geneva, World Health Organization, International Programme on Chemical Safety (International Chemical Safety Cards 0020, 0116, 0117, 0404, 1075 and 1318; 2005–2007 Available:http://www.who.int/ipcs/publications/icsc/en/index.html).

56. Agency for Toxic Substances and Disease Registry (ATSDR). Toxicological profile for nickel. Atlanta, GA: U.S. Department of Health and Human Services, Public Health Service; 2005. Available:https://www.atsdr.cdc.gov/ToxProfiles/TP.asp?id=245&tid=44

57. WHO (World Health Organization). Arsenic. Department of public health, environmental and social determinants of health world health organization 20 Avenue appia, 1211 Geneva 27, Switzerland; 2018. Available:https://www.who.int/news-room/fact-sheets/detail/arsenic

58. Quansah R, Armah FA, Essumang DK, Luginaah I, Clarke E, Marfoh K. Association of arsenic with adverse pregnancy outcomes/infant mortality: A systematic review and meta-analysis. Environ Hlth Persp. 2015;123:412–421.

59. Farzan SF, Karagas MR, Chen Y. In utero and early life arsenic exposure in relation to long-term health and disease. Toxicol Appl Pharmacol. 2013;272(2):384–390.

60. Agency for Toxic Substances and Disease Registry (ATSDR) Toxicological profile for cobalt. Atlanta, GA: U.S. Department of Health and Human Services, Public Health Service; 2004. Available:https://www.atsdr.cdc.gov/ToxProfiles/tp.asp?id=373&tid=64

61. Gad SC. Cobalt. Encyclopedia of Toxicology, 3rd edition. 2014:996–998.

62. Shrivastava R, Upreti RK, Seth PK, Chaturvedi UC. Effects of chromium on the immune system. FEMS Immunol Med Microbio. 2002;34(1):1–7.

63. Anderson RA. Chromium in the prevention and control of diabetes. Dia Met. 2000;26(1):22-27.

64. ATSDR (Agency for Toxic Substances and Disease Registry). Toxicological Profile for Chromium; 2000. Available:http://www.atsdr.cdc.gov/toxprofiles/tp.asp?id=62&tid=17

65. Baars AJ, Theelen RMC, Janssen PJCM, Hesse JM, van Apeldoorn MV, Meijerink MV. Re-evaluation of human-toxicological maximum permissible risk levels, Microsoft Word - 711701025.doc (openrepository.com); 2001.
66. US Environmental Protection Agency (USEPA). Integrated risk information system of the US environmental protection agency; 2012.

67. Integrated Risk Information System (IRIS) Nickel, soluble salts CASRN Various | DTXSID5024215 | IRIS | US EPA, ORD; 1991.

Available:https://cfpub.epa.gov/ncea/iris/iris_documents/documents/subst/0271_summary.pdf#n meddest=rfd

© 2021 Ibegbu et al.; This is an Open Access article distributed under the terms of the Creative Commons Attribution License (http://creativecommons.org/licenses/by/4.0), which permits unrestricted use, distribution, and reproduction in any medium, provided the original work is properly cited.

Peer-review history:
The peer review history for this paper can be accessed here:
http://www.sdiarticle4.com/review-history/65143