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Chemical contamination of food: Bioaccumulation and potential consumer exposure to metal residues in vegetables.

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Abstract

One of the most significant causes of health problems worldwide is heavy metal contamination of vegetables. Hence, the study aimed to evaluate the concentration of ten heavy metals in commonly consumed vegetables and determine the health implications of their consumption. The vegetables studied included waterleaf (*Talinum triangulare*), fluted pumpkin (*Telferia occidentalis*), and green (*Amaranthus viridis*) sold at a market in Anambra State. The concentrations of heavy metals, namely cobalt, copper, zinc, cadmium, lead, iron, manganese, chromium, nickel, and mercury, were analysed using atomic absorption spectrometer (AAS). The study compared the results with Codex food grade standards and assorted (sub) tropical vegetables. The results showed that the concentration of mercury, cadmium and lead monitored in the vegetables exceeded the permissible limits set by WHO/FAO standards. This indicates a potential public health threat, as high concentrations of these heavy metals can cause health problems. The study recommends continuous monitoring of trace element levels in vegetables sold to consumers, as sources of contamination can vary. The findings of this study are significant for policymakers, health experts, and the general public because it highlights the need for food safety measures and guidelines to prevent heavy metal contamination in vegetables and protect public health.

Keywords: food safety, dietary toxicity, public health, heavy metals, Anambra State.

Introduction

Vegetables are recognized to have favorable nutritional benefits on human health due to their significant performance in preventing a number of chronic diseases. However, the quality and safety of vegetables are seriously threatened by heavy metal contamination brought on by soil and air contamination (Patrick and Chioma, 2017). Additionally, eating plants tainted with heavy metals puts animals and the entire food chain at danger. This is because these metals rapidly accumulate to dangerous amounts in organisms due to their non-biodegradability (Farooq *et al*., 2008), non-thermodegradability (Sharma *et al*., 2008), and lengthy biological half-

lives (Arora *et al*., 2008). Depending on the length of exposure to the metals and their inflow within the body, these heavy metals can cause varied degrees of sickness (Farooq *et al*., 2008).

The quality of vegetables produced across the country is paradoxically declining as pesticide use to "improve" crop productivity increases. The heavy metal components of these pesticides and the hazards associated with eating plants polluted by them are of special concern. Heavy metals, such as mercury (Hg), copper (Cu), lead (Pb), and zinc (Zn), pose serious risks to human health and have been found in developing nations like Nigeria, at significant concentrations in food crops like fruits, vegetables, and cereals. This has sparked a discussion about the effectiveness of food quality assurance and safety assessment measures (Yusuf *et al*., 2003; Ezeonyejiaku and Obiakor, 2017).

Through ingestion of tainted water, inhalation of dust, or direct consumption of plants cultivated in metal-contaminated soils, heavy metals can enter the body in a number of different ways (Chary *et al*., 2008, Islam *et al*., 2007). Additionally, plants are recognized as the main source of metals in the human diet due to their capacity to bioaccumulate toxic heavy metals in their cationic and anionic forms from the soil through hyperaccumulation, which is caused by vacuolar compartmentalization and chelating while also accumulating essential nutrients like nitrogen (N), phosphorus (P), and potassium (K). Vegetables can absorb and bioaccumulate heavy metals due to a variety of circumstances, including climate, atmospheric depositions, soil composition, heavy metal concentrations, and occasionally the maturity of the plant at harvest. These human-made activities typically cause pollution, especially in underdeveloped nations where sub-par waste management is the norm (Babayemi and Dauda, 2009).

As most of the heavy metals released by moving vehicles and some industries are trapped and collected in the vegetables, increasing the amount of heavy metals in the vegetables, air pollution may also endanger post-harvest vegetables during transportation and marketing. The addition of manure, the use of sewage sludge, and the application of fertilizer are additional anthropogenic activities that will also increase the concentration of heavy metals in vegetables. These activities may affect the uptake of heavy metals by altering the physico-chemical characteristics of the soil, such as pH, organic matter, and the bioavailability of heavy metals in the soil (Yusuf and Osibanjo, 2006). In comparison to non-leafy vegetables, leafy vegetables are known to acquire more heavy or trace metals. As a result, they may adhere to the plant's surface or enter plant cells (absorption). Heavy metals are typically partitioned after intake, with leaves and roots accumulating higher quantities than fruits (Sharma *et al*., 2008). Aerosols containing metal contaminants are a threat to agricultural areas close to roads or industrial zones. In addition to being deposited on the soil and then absorbed by vegetables, these aerosols can also be applied on the leaves or fruit of these vegetables (Sharma *et al*., 2008; Singh *et al*., 2011).

Although heavy metals have been the subject of in-depth research and the development of trustworthy regulations in many jurisdictions, little is known about their ecotoxicity. Due to their potential effects on human health, the few heavy metals that are both environmentally and biologically significant include cadmium (Cd), lead (Pb), zinc (Zn), copper (Cu), arsenic (As), nickel (Ni), chromium (Cr), manganese (Mn), and iron (Fe). Numerous pathways for human exposure to these heavy metals have been identified (Patrick-Iwuanyanwu and Chioma, 2017; Radwan and Salama, 2006; Roba *et al*.,

2016; Sharma *et al*., 2008; Singh *et al*., 2011)

Due to the immediate risk that these metals represent to humans and the rising levels of environmental pollution, it is crucial to regularly evaluate the quality of food products in contaminated areas using these metal analyses. The assessment will raise public awareness of the dangers related to eating food that contains significant amounts of heavy metals and provide information on the degree of metal contamination and, consequently, the effect on food safety standards and consumer risk (Ezeonyejiaku and Obiakor, 2016; Roba *et al*., 2016).

Due to inadequate risk assessment, communication, and resource shortages, the harmful consequences of heavy metal pollution on vegetables have not received enough attention in Nigeria. Less research has been done on the consequences of heavy metal contamination on human health in regularly consumed vegetables (Ezeonyejiaku and Obiakor, 2017). Hence, the study determines the levels of heavy metals in the waterleaf (*Talinum triangulare*), fluted pumpkin (*Telferia occidentalis*), and green amaranthus (*Amaranthus viridis*) sold at Eke-Awka market. Metal smelting activities have an established history in the Awka city (Okonkwo and Ibeanu, 2017). Also, in order to compile fundamental information on the concentration of heavy metals and compare it to globally recognized norms for use in initial exposure assessments for the local population, this market survey set out to collect that information.

Methods

Study location and sample collection

Vegetable samples from Eke-Awka in Awka South, which feeds the entire Local Government Area and the neighbouring towns of Awka North, were gathered. Awka South is in the Anambra State of south-eastern Nigeria, within the coordinates of 6.642° N and 7.067° E (**Figure 1**). The area is characterized by two distinct seasons that are influenced by two dominant winds: the north-eastern dry winds from across the Sahara Desert and the southwestern monsoon winds from the Atlantic Ocean. April through October brings seven months of intense tropical rain, followed by five months of aridity (November–March). The average weather of Awka South is hot and muggy, ranging between 27 and 28 degrees Celsius from July through December but reaching 35 degrees Celsius from February to April (Okoye *et al*., 2022).

According to projections for the population for 2017, Awka South is expected to have about 400,000 residents (NPC, 2017). Awka city, the capital of Anambra State, Amawbia, Ezinato, Nibo, Nise, Umuawulu, Isiagu, Okpuno, and Mbaukwu make up the region. Many commercial and social facilities can be found in Awka City, which also has a heritage of indigenous technology and crafts like wood processing, metal smelting, and blacksmithing. Through the haphazard disposal and dumping of tailings, the area's agricultural, wood processing, and industrial metal activities have uncoordinated waste management systems that have worsened environmental degradation (Okonkwo and Ibeanu, 2017). Due to the rapid advancement of technology, these metal processing operations have drastically decreased, but unregulated artisanal production is still practiced (Okonkwo and Ibeanu, 2017). The city is also one of southeast Nigeria's most significant commercial, industrial, cultural, and political hubs. It is still heavily urbanizing and developing its infrastructure. Awka South's industrial facilities are dispersed throughout the suburbs and city centre.

At the market (Eke-Awka), local vegetables waterleaf (*Talinum triangulare*), fluted pumpkin (*Telferia occidentalis*), and green (*Amaranthus viridis*) were acquired from a wide range

of sellers, including those who sold them directly to customers on market tables and shelves. The farmers in the area provided all the vegetables according to the sellers. The vegetables were identified and authenticated by a plant taxonomist at the Department of Botany, Faculty of Bio-sciences, Nnamdi Azikiwe University, Awka.

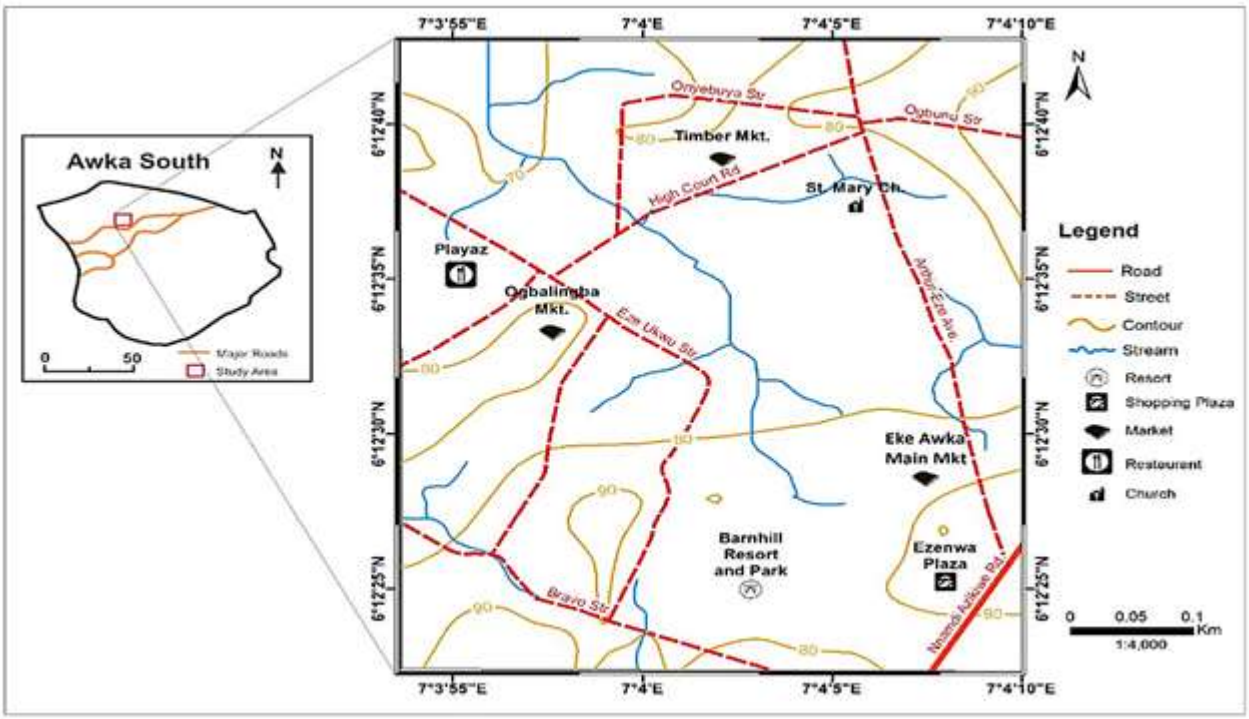


Figure 1: Map of the study area (Eke-Awka)

Sample preparation

To avoid additional atmospheric deposition that could interfere with elemental analysis, vegetable samples were transported to a laboratory in an airtight container. Deionized water was used to wash the recently acquired samples in order to remove any obvious dirt. To quickly wipe away the wetness, blotting paper was utilized. The samples were then divided into smaller pieces and accurately and consistently weighed in preparation for various analyses.

Analysis of heavy metals in vegetable samples

Total Cd, Pb, Zn, Cu, Co, Ni, Cr, Mn, Fe, and Hg were determined in all samples using standard techniques with modifications (Sharma *et al*., 2008; Roba *et al*., 2016; Radwan and Salama 2006). Throughout the entire metal determination, analytical grade reagents with purity ranging from 98 to 99.99% were utilized. At 55°C, samples were dried in an oven. The vegetables were collected, crushed, and dried in a muffle furnace for three hours (3hrs). Then, 2g of each sample was weighed out and placed in a digestion flask with 20ml of an acid mixture made up of 650ml of concentrated HNO_3, 8ml of perchloric acid, and 20ml of concentrated $H2SO_4$. Heat was applied to the mixture in the flask until a clear digest was produced. Distilled water was used to dilute the digest to the 100ml threshold. The sample was then properly mixed by shaking, and 100 ml of it was transferred into a glass beaker with a capacity of 250 ml. Also, 1.5 ml of concentrated nitric acid was added to the beaker, and it was heated to boil until the volume was reduced to 15-20 ml. The liquid was cooled, transported, and diluted with metal-free distilled water to a volume

of 100ml. The sample was inhaled into the air-acetylene flame, which was oxidizing. The sensitivity for 1% absorption was seen when the aqueous sample was aspirated. After cooling, digested samples were diluted to 50 ml, and the concentration of Cd, Pb, Zn, Cu, Co, Ni, Cr, Mn, Fe and Hg was determined using atomic absorption spectrophotometry (AA320N Atomic Absorption Spectrophotometer).

Quality Control

The National Institute of Standards and Technology (NIST) Standard Reference Material 1515, fluted pumpkin (NIST Standard Reference Material 1575a), and green Amaranthus (NIST Standard Reference Material 1568a) were used as certified reference materials (CRM) to monitor the accuracy of the instrument and the efficacy of the method extraction for each analytical batch. All of the analysed metals were measured as part of the analytical quality control using mixed element internal standards. Thus, reagent blanks and CRMs were included in the analysis of a total of 25 separate digests. When compared to the theoretical or certified values for the elements from CRM, the mean recoveries fell within an acceptable range (75–98.5%). Each piece of glass used in the analyses was cleaned with a detergent-free solution, then submerged in acid (10% hydrochloric acid), followed by a rinse with distilled water devoid of metals. Metal concentrations were measured at an instrumental detection limit of 0.001 g/g and given in μg/g dry weight.

Statistical Analysis

Microsoft Excel (version 2016) and IBM SPSS Statistics (version 21, SPSS Inc., Chicago, IL, USA) were used to analyse the study's data with an alpha error of 0.05 and a 95% confidence interval. The Shapiro- Wilk test and Levene's test were used to objectively assess the homogeneity of variance and the normality of the data distribution (Shapiro and Wilk, 1965). Because there are multiple variables, an ANOVA was employed to determine whether there is a significant difference. The Duncan's Multiple Range Test (DMRT) was used to separate the sample means.

Results

The mean Cd, Pb, Zn, Cu, Co, Ni, Cr, Mn, Fe and Hg concentrations for the vegetable samples collected from Eke-Awka market and the corresponding comparisons of the metal concentrations with Codex guideline levels are presented in **Figures 2–10**. The result revealed that cobalt was highest in green leaf (0.103±0.002 μg/g) while least in fluted pumpkin and water leaf. There was significant difference between mean cobalt concentrations in the three vegetables sampled (P <0.00). However, in comparison with the standard by WHO/FAO the mean cobalt value of vegetables sampled in Eke-Awka market was lower than the WHO/FAO acceptable limit (**Figure 2**).

The result revealed that copper was highest in green (1.198±0.001 μg/g), followed by fluted pumpkin (0.120±0.001 μg/g) while least in water leaf (0.000±0.000 μg/g). There was significant difference between mean copper concentrations in the three vegetables sampled (P <0.00). However, in comparison with the standard by WHO/FAO, the mean copper value of vegetables sampled in Eke-Awka market was lower than the WHO/FAO acceptable limit (**Figure 3**).

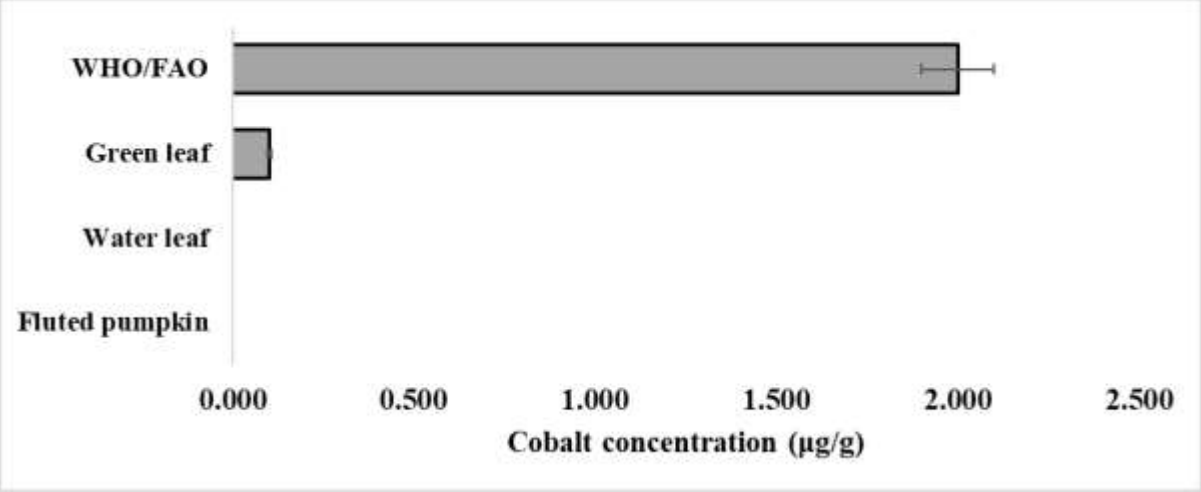


Figure 2: Cobalt concentration of the vegetables sampled in Eke-Awka market survey. Values represent mean cobalt concentration ± standard deviation, n = 4. Mean values bearing different superscripts are significantly different (Duncan Multiple Range Test, $P < 0.05$). WHO/FAO indicates Codex food grade standard.

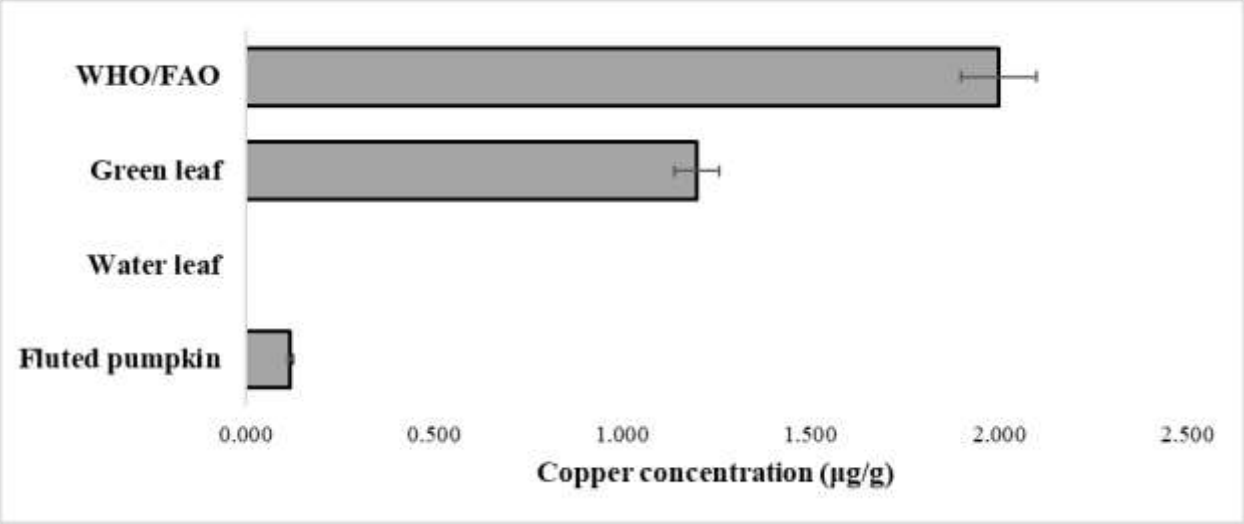


Figure 3: Copper concentration of the vegetables sampled in Eke-Awka market survey. Values represent mean copper concentration ± standard deviation, n = 4. Mean values bearing different superscripts are significantly different (Duncan Multiple Range Test, $P < 0.05$). WHO/FAO indicates Codex food grade standard.

The result revealed that zinc was highest in water leaf (1.974±0.001 µg/g), followed by green (1.876±0.005 µg/g) while least in fluted pumpkin (1.257±0.002 µg/g). There was significant difference between mean zinc concentrations in the three vegetables sampled (P <0.00). However, in comparison with the standard by WHO/FAO, the mean zinc value of vegetables sampled in Eke-Awka market was lower than the WHO/FAO acceptable limit (**Figure 4**).

The result revealed that cadmium was highest in green leaf (0.940±1.329 µg/g), followed by fluted pumpkin (0.027±0.002 µg/g) while least in waterleaf (0.000±0.000 µg/g). There was significant difference between mean cadmium concentrations in the three vegetables sampled (P <0.00). However, in comparison with the standard by WHO/FAO, the mean cadmium value of fluted pumpkin and water leaf sampled in Eke-Awka market Awka was lower than

the WHO/FAO acceptable limit while those of green leaf was higher (**Figure 5**).

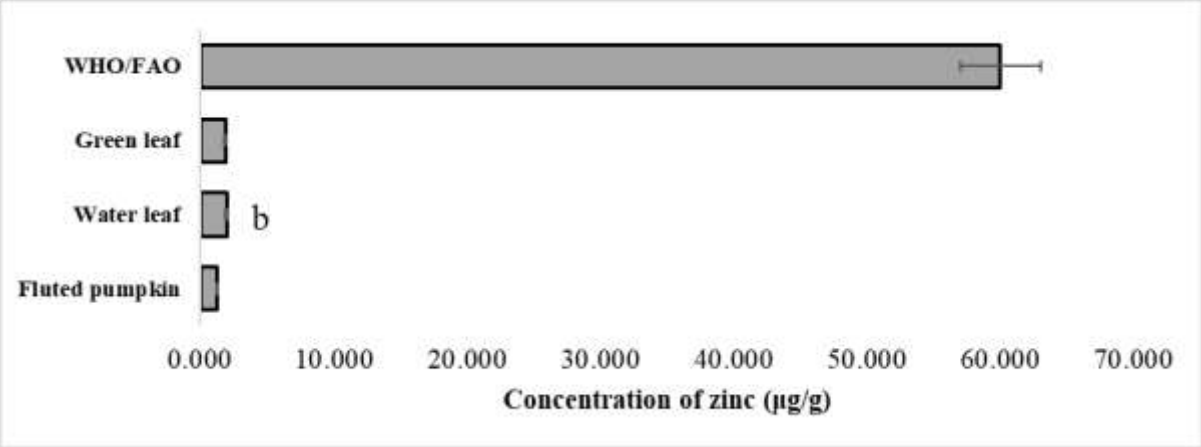


Figure 4: Zinc concentration of the vegetables sampled in Eke-Awka market survey. Values represent mean zinc concentration ± standard deviation, n = 4. Mean values bearing different superscripts are significantly different (Duncan Multiple Range Test, $P < 0.05$). WHO/FAO indicates Codex food grade standard.

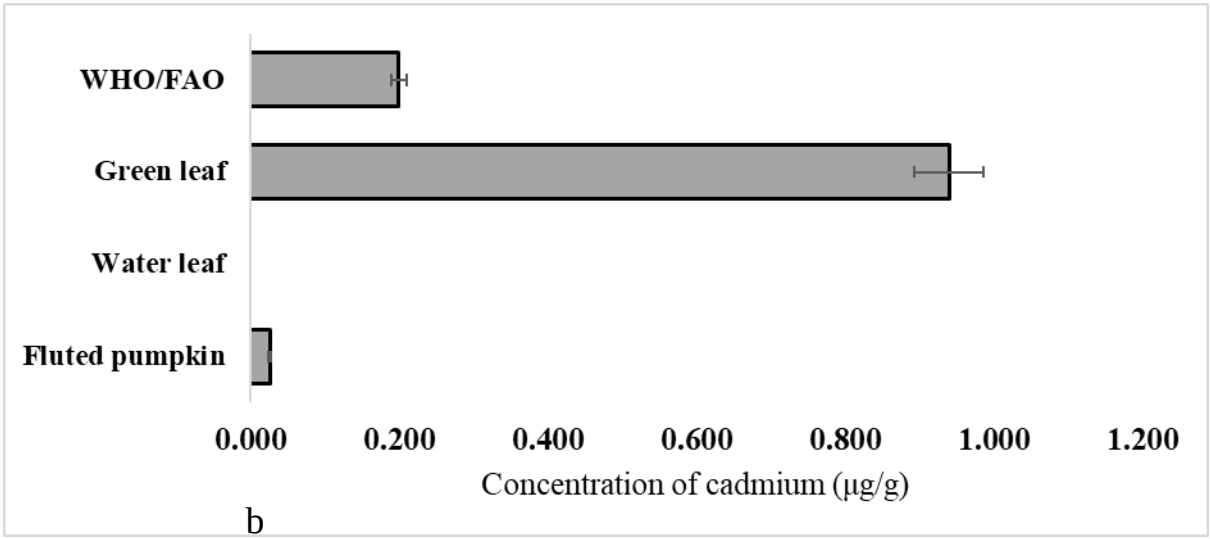


Figure 5: Cadmium concentration of the vegetables sampled in Eke-Awka market survey. Values represent mean cadmium concentration ± standard deviation, n = 4. Mean values bearing different superscripts are significantly different (Duncan Multiple Range Test, $P < 0.05$). WHO/FAO indicates Codex food grade standard.

The result revealed that lead was highest in water leaf (0.607±0.001 µg/g), followed by green (0.603±0.002 µg/g) while least in fluted pumpkin (0.000±0.000 µg/g). There was significant difference between mean lead concentrations in the three vegetables sampled (P <0.00). However, in comparison with the standard by WHO/FAO, the mean lead value of vegetables sampled in Eke-Awka market was higher than the WHO/FAO acceptable limit except Fluted pumpkin (**Figure 6**).

The result revealed that iron was highest in green (3.080±0.014 µg/g), followed by fluted pumpkin (2.664±0.004µg/g) while least in water leaf (2.253±0.001 µg/g). There was significant difference between mean iron concentrations in the three vegetables sampled (P<0.00). However, in comparison with the standard by WHO/FAO, the mean iron value of vegetables sampled in Eke-Awka market was lower than the WHO/FAO acceptable limit (**Figure 7**).

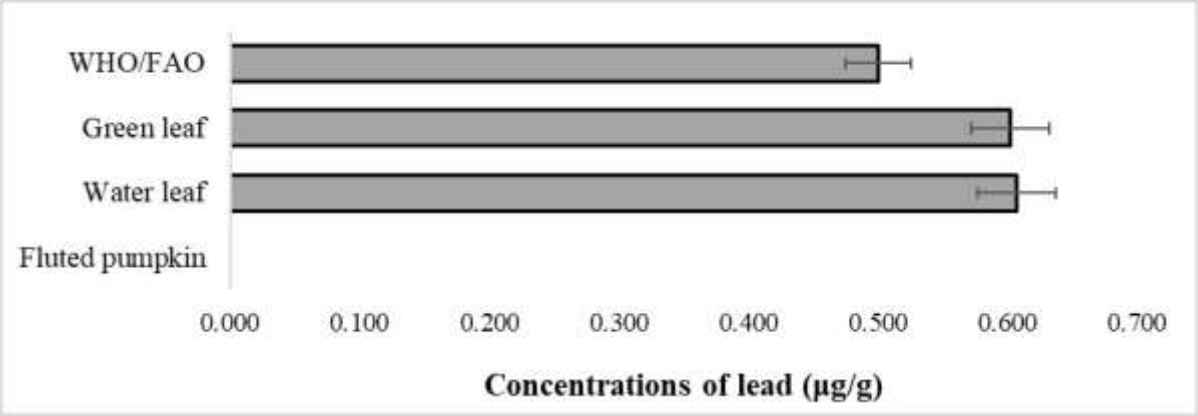


Figure 6: Lead concentration of the vegetables sampled in Eke-Awka market survey. Values represent mean lead concentration ± standard deviation, n = 4. Mean values bearing different superscripts are significantly different (Duncan Multiple Range Test, $P < 0.05$). WHO/FAO indicates Codex food grade standard.

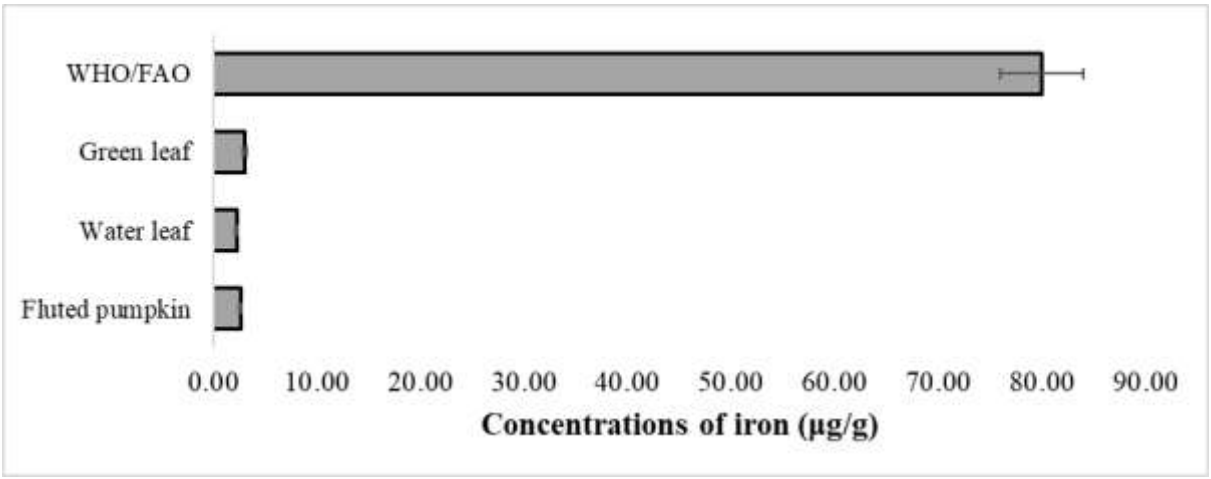


Figure 7: Iron concentration of the vegetables sampled in Eke-Awka market survey. Values represent mean iron concentration ± standard deviation, n = 4. Mean values bearing different superscripts are significantly different (Duncan Multiple Range Test, $P < 0.05$). WHO/FAO indicates Codex food grade standard.

The result revealed that manganese was highest in water leaf (3.327±0.001 µg/g), followed by green (1.258±0.001 µg/g) while least in fluted pumpkin (0.975±0.021 µg/g). There was significant difference between mean manganese concentrations in the three vegetables sampled (P<0.00). However, in comparison with the standard by WHO/FAO, the mean manganese value of vegetables sampled in Eke-Awka market was lower than the WHO/FAO acceptable limit (**Figure 8**).

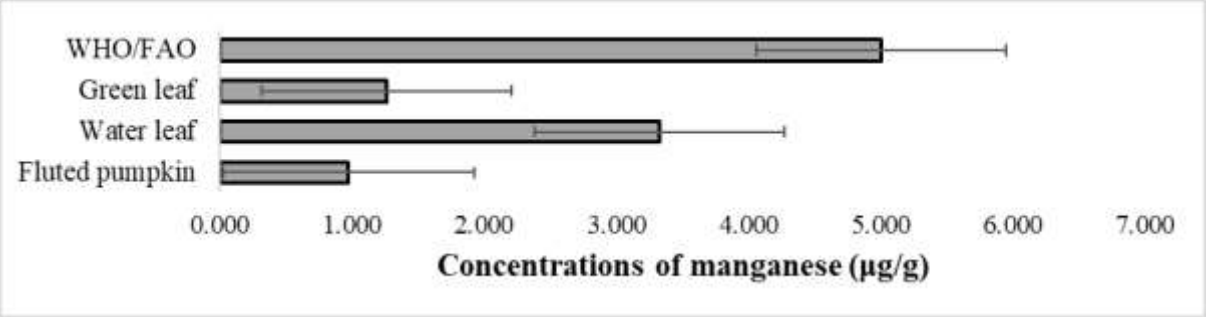


Figure 8: Manganese concentration of the vegetables sampled in Eke-Awka market survey. Values represent mean manganese concentration ± standard deviation, n = 4. Mean values bearing different superscripts are significantly different (Duncan Multiple Range Test, $P < 0.05$). WHO/FAO indicates Codex food grade standard.

The result revealed that chromium was not detected in the vegetable samples (0.000±0.000 µg/g).). However, in comparison with the standard by WHO/FAO, the mean chromium value of vegetables sampled in Eke-Awka market was lower than the WHO/FAO acceptable limit.The result revealed that nickel was highest in green leaf (0.337±0.001 µg/g), followed by fluted pumpkin (0.299±0.001 µg/g) while least in water leaf (0.148±0.001 µg/g). There was significant difference between mean nickel concentrations in the three vegetables sampled (P <0.00). However, in comparison with the standard by WHO/FAO, the mean nickel value of vegetables sampled in Eke-Awka market was lower than the WHO/FAO acceptable limit.

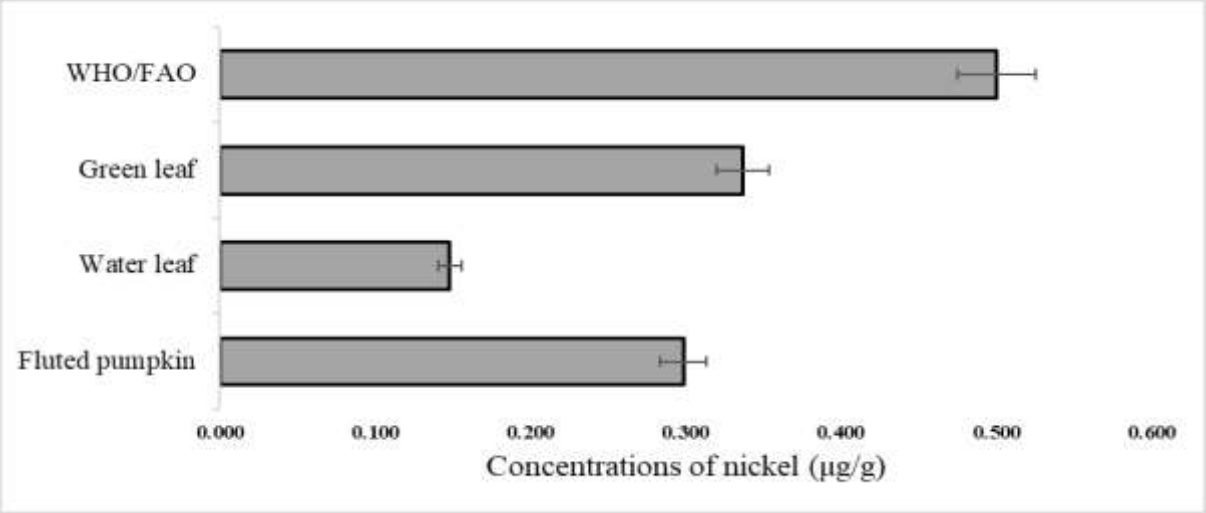


Figure 9: Nickel concentration of the vegetables sampled in Eke-Awka market survey. Values represent mean nickel concentration ± standard deviation, n = 4. Mean values bearing different superscripts are significantly different (Duncan Multiple Range Test, $P < 0.05$). WHO/FAO indicates Codex food grade standard.

The result revealed that mercury was highest in green (2.727±0.003 µg/g), followed by fluted pumpkin (2.13±0.014 µg/g) while least in water leaf (1.935±0.007 µg/g). There was significant difference between mean mercury concentrations in the three vegetables sampled (P <0.00). However, in comparison with the standard by WHO/FAO, the mean mercury value of vegetables sampled in Eke Awka market Awka was higher than the WHO/FAO acceptable limit.

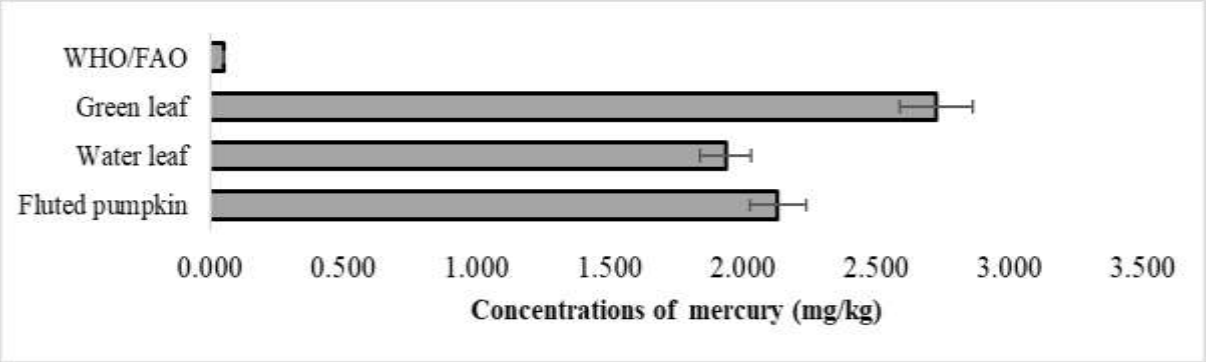


Figure 10: Mercury concentration of the vegetables sampled in Eke-Awka market survey. Values represent mean mercury concentration ± standard deviation, n = 4. Mean values bearing different superscripts are significantly different (Duncan Multiple Range Test, $P < 0.05$). WHO/FAO indicates Codex food grade standard.

Discussion

The study illustrates the possible effects of anthropogenic activities on metal mobility, deposition, and food contamination while demonstrating how the amounts of heavy metals in vegetables vary. In order to evaluate food quality and make recommendations based on a clear understanding of the risks to human health, the current study examined concentrations of cobalt, copper, zinc, cadmium, lead, iron, manganese, nickel, and mercury in three sampled vegetables, *Talinum triangulare*, *Telferia occidentalis*, and *Amaranthus viridis*. Vegetables contaminated with heavy metals could be harmful to both humans and animals' health. Because of the area's open market system and the rapid structural changes occurring in its urban ecology, such as building and road construction, Awka South was chosen for the current survey. In many instances, these actions are not carefully planned. The region frequently experiences meteorological conditions including dust pollution and fog, and marketplaces are randomly positioned along roadways. As a result, monitoring food contamination by metals and dangerous chemicals is essential for determining dietary exposures and reducing them (WHO, 2015, Ali and Al-Qahtani, 2012, Yusuf *et al*., 2003, Ezeonyejiaku and Obiakor, 2016).

However, heavy metals were present to variable degrees or concentrations, with the exception of chromium, which was not detected in all the three of the analyzed vegetables. This work supports earlier research by Das *et al*. (2008), which found that certain of these elements (Fe, Cu, Ni, and Zn) are present in our environment and diet and are indeed essential for optimum health. However, they might induce short-term or long-term harm when present in excessive amounts.

The results showed that the examined vegetables had higher total mercury concentration (2.13±0.014µg/g - 1.935±0.007µg/g - 2.727±0.003µg/g) which is more or higher than the WHO/FAO acceptable limit (0.05µg/g). The high mercury (Hg) concentrations compared to WHO/FAO standard is particularly striking because of its high toxicity and public health risk. The elevated concentration of mercury (Hg) may be caused by significant traffic congestion near the market. It might also be a result of improper handling and processing, or it might be related to the kind of agrochemicals used in farming of the vegetables. Among the investigated heavy metals, mercury is one of the most hazardous elements, and prolonged exposure can result in kidney, brain, and fetal damage. This supports prior studies that found that heavy metals like lead,

mercury, and cadmium are harmful even at low doses and have been linked to a number of illnesses like cancer, metabolic problems, and nervous system ailments (Sharma *et al*. 2008 and Singh *et al*. 2011). This further supports the findings of Sharma *et al*. (2008) and Singh *et al*. (2011), which found a link between developmental abnormalities in children and trace elements including lead (Pb) and mercury (Hg).

The results also showed that there was higher concentration of lead (Pb) in waterleaf and green leaves with the range of 0.607±0.001µg/g - 0.603±0.002µg/g which is above the WHO/FAO permissible limit of 0.50µg/g. Lead was not detected in fluted pumpkin. Leaded gasoline, lead-based paints, and batteries have historically been the main sources of lead exposure. These sources are consistent with the study area's environmental circumstances, which include exposure to high levels of traffic congestion, which releases leaded gasoline into the atmosphere, as well as the presence of numerous paint industries in Awka and its surroundings. We cannot completely rule out the potential that these metals were also present in the vegetable samples as a result of direct uptake from soil, where they were cultivated. Although air and surface deposition is thought to be a key carrier of metal mobilization (Samsoe-Petersen *et al*., 2002; Roba *et al*., 2016). This finding supports a prior study by (Edem *et al*. (2009) that found that certain heavy metals become hazardous to our health if their levels rise above tolerable limits. It is for this reason that (Patra *et al*., 2011) stated in their study that lead is one of the most dangerous cumulative environmental contaminants that affects all biological systems through exposure to air, water, and food sources. In addition, heavy lead consumption is deemed harmful and is linked to behavioral abnormalities, hearing deficiencies, neuromuscular weakness, and reduced cognitive processes in people, according to Flora *et al*. (2012).

Additionally, cadmium concentrations in green leaves were found to be greater than the WHO/FAO standard or permitted level. In waterleaf and fluted pumpkin, cadmium concentrations were found to be low and below the WHO/FAO allowed limit. However, since vegetables are a great source of vitamins, minerals, and fiber and also have preventive and advantageous antioxidative effects, it is important to periodically evaluate these heavy metals to prevent exceeding the permitted levels (Olujimi *et al*., 2015, Ogundele *et al*., 2017). However, given the level of pollution currently present in Nigerian cities, it is necessary to investigate the practices involved in the production of these vegetables by farmers to ensure food safety

It is crucial to periodically evaluate the quality of food items in this region by metal analysis due to the significance of these metals for humans and the associated threat they cause, as well as a growth in environmental contamination. The evaluation will raise public knowledge of the pertinent risks connected with consuming foods that contain significant amounts of heavy metals and provide information on the degree of metal contamination and, consequently, the effect on food safety standards and consumer risk (Ezeonyejiaku and Obiakor, 2016). Given that recent studies have shown health consequences at relatively low concentrations, even while other heavy metal concentrations were lower than WHO/FAO limits, it is necessary to study whether these low exposures may increase the likelihood of unfavorable health effects. Additionally, it is important to discourage anthropogenic activities such as the use of pesticides, fertilizers, and insecticides that contain heavy metals because they increase the amount of these heavy metals in the environment and are then absorbed by the vegetables that

humans and other animals eat, endangering their health.

5. Conclusion

The study evaluated the levels of heavy metals in waterleaf (*Talinum triangulare*), fluted pumpkin (*Telferia occidentalis*), and green amaranthus (*Amaranthus viridis*) sold at Eke-Awka market. Waterleaf, green, and fluted pumpkins are important sources of nutrients for both people and animals. The presence of heavy metals in various vegetables at varying levels or concentrations has been demonstrated or discovered by this study.The findings of the study showed that the concentration of cobalt, copper, zinc, iron, manganese, chromium, and nickel were below the recommended limit of WHO/FAO for food grade standard. This implies that there is no risk of consuming these metals from the vegetables sold at the market. However, the result of the study showed that the concentration of cadmium, lead and mercury were above the recommended limit of WHO/FAO for food grade standard. The high levels of cadmium (Cd), lead (Pb) and mercury (Hg) found in the vegetable suggest that people may be eating heavy metals, which is potentially very dangerous for the public's health. Hence, there is need to investigate the practices involved in the cultivation of these vegetables to check the potential health risk associated with cadmium (Cd), lead (Pb) and mercury (Hg) in the study area. Furthermore, it is advised that more research be done on the heavy metals found in the produce and other edible vegetables sold in Eke Awka.

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APPENDIX I

Table 1: Average heavy metal concentrations in vegetables collected for the study

Vegetables	Cobalt (µg/g)	Copper (µg/g)	Zinc (µg/g)	Cadmium(µg/g)	Lead(µg/g)	Iron (µg/g)	Manganese(µg/g)	Chromium (µg/g)	Nickel(µg/g)	Mercury(µg/g)
Fluted pumpkin	0.00±0.00a	0.120±0.001b	1.257±0.002a	0.027±0.002a	0.000±0.000a	2.664±0.004b	0.975±0.021a	0.000±0.000	0.299±0.001b	2.13±0.014b
Water leaf	0.00±0.00a	0.000±0.000a	1.974±0.001c	0.000±0.000a	0.607±0.001b	2.253±0.001a	3.327±0.001c	0.000±0.000	0.148±0.001a	1.935±0.007b
Green leaf	0.103±0.002b	1.198±0.001c	1.876±0.005b	0.940±1.329a	0.603±0.002b	3.080±0.014c	1.258±0.001b	0.000±0.000	0.337±0.001c	2.727±0.003a
WHO/FAO Acceptable limit (µg/g)	2	2	60	0.2	0.5	80	5	1.2	0.5	0.05

Abbreviation: Co, cobalt; Cu, copper; Zn, zinc; Cd, cadmium; Pb, lead; Fe, iron; Mn, manganese; Cr, chromium; Ni, nickel; and Hg, mercury.
*Mean values bearing different superscript along the same column are significantly different (Analysis of Variance, ANOVA, P <0.05). Mean values are reported in dry weight. WHO/FAO indicates codex food grade standard (Codex, 1995).