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Public Health Implications of Heavy Metal Contamination of Leaves and Stems of Amarantus Hybridus (African spinach) Consumed in Nigeria

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Abstract

The objective of this study was to measure the concentration and pattern of distribution of Cd, Cr, Co, Cu, Mn, Ni, Pb, and Zn on the leaves and stem of Amaranthus hybridus (African Spinach) one of the most consumed leafy vegetables in Nigeria with an estimated population of over 200 million people, findings from this study showed that with the exception of Cd and Co two heavy metals of public health importance, the results of the analysis for heavy metals using atomic absorption spectrophotometer were within the maximum permissible limits set by FAO/WHO Committee of the Codex Alimentarius Commission and Agency for toxic substance disease registry (ATSDR). The results showed that while the values for Cd were within acceptable limits in the leaves, the concentration in the stem ranged of 0.007 to 0.3358 ppm above the maximum limit of 0.1ppm. The result also showed the presence of Co at a concentration of range of 0.1289 to 0.3487ppm in the leaves and 0.1470 to 0.3719 ppm in the stems above the maximum permissible limit set by the Agency for Toxic Substance Disease Registry (ATSDR) of between 0.05 to 0.1 ppm. The potential consequences of exposure to harmful substances, on either a population or an individual basis, is a fundamental concern in epidemiology and public health, these findings have major public health implication for food safety and quality as the likely accumulation of Co and Cd in the body through diets over a long period of time can further complicate the current public health crisis in Nigeria.

Introduction

Amaranthus hybridus also known as African spinach or pigweed is a nutritious leafy vegetable, a member of the Amaranthaceae family widely cultivated and consumed in Nigeria. It is used for a variety of purposes ranging from food to medicine (Omosun *et al*., 2008). The central stem of the plant is light greenish or tan-green, and ribbed, the leaves are ovate or elliptic-ovate, smooth or slightly undulate a

long the margins, and pubescent or hairless, there may be red tints along the margins of the leaves and elsewhere. The leaves and stem can be eaten raw or cooked and used as a spinach substitute.

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Seeds are used as a cereal substitute and used in porridges and bread. (PFAF, 2019) In Nigeria, the plant leaves combined with condiments are used to prepare soup sauce for rice and yam, In Congo, they are eaten as spinach or green vegetables while in Mozambique and in West Africa they boiled and mixed with a groundnut sauce and eaten as salad (Akubugwo *et al*., 2007).

An Amaranthus hybridus (African Spinach) plant

Soup Made from Amaranthus hybridus (African Spinach)

The green vegetables have long been recognized as the cheapest and most abundant potential source of protein because of its ability to synthesize amino acids from a wide range of virtually unlimited and readily available primary materials such as sunlight, water, carbon dioxide, atmospheric nitrogen like in legumes (Adeyeye and Omolayo, 2011).

Amaranthus hybridus is widely consumed in Nigeria and they are highly valued due to the appreciable amount of nutrients and mineral elements they provide in diets to supplement the daily requirement by the body (Oyelola et al., 2014). The current high demand for leafy vegetables in the cities and towns has stimulated the growth of market gardening along perennial rivers and streams in major towns and cities of Nigeria and A. hybridus is a common species in waste places, (Inyang et al.,2018). increasing their tendency for contamination.

Heavy metals are individual metals and metal compounds which are all naturally occurring substances which are often present in the environment at low levels. In larger amounts, they can be dangerous and can impact human health negatively, the consumption of food crops contaminated with heavy metals is a major food chain route for human exposure (Khan et al., 2008). Rapid industrialization, urbanization, the haphazard use of variety of chemicals agents and pollution of agricultural lands and air have led to the accumulation of unacceptable levels of heavy metal in the environment, the resulting uptake, transformation and bio-accumulation of heavy metals by food crops grown in these areas leads to the heavy metal contamination of food with a corresponding negative impact on food quality, safety and ultimately the health of the population that consume such food (Khanna, 2011).

As research in medical science unearths new evidence linking heavy metals to more debilitating health conditions, heavy metals which are also known as metalloid in scientific literature are increasingly becoming one of the major public health concerns of the 21st century as countries rise to the challenge of issues relating to food security and food safety. The standard for the evaluation of heavy metals and other contaminants in foods is in report of the Joint FAO/WHO Expert Committee (JECFA). The JECFA is an international scientific expert committee jointly administered by the WHO and the Food and Agriculture Organization of the United Nations (FAO). The committee has been meeting since 1956 to evaluate the safety of naturally occurring toxicants, food additives, contaminants, and residues of veterinary drugs in food (WHO, 2019). This independent scientific expert committee performs human health risk assessment, food consumption and exposure assessment, toxicology, epidemiology, and provides advice and benchmark for acceptable limits found in food. Another important institution that performs similar role and provides reliable template for standards is the Agency for toxic substance disease registry (ATSDR) a federal public health agency within the United States Department of Health and Human Services charged with protecting communities from harmful health effects related to their exposure to natural and man-made hazardous substances (ATSDR, 2019).

Research objectives

To determine and compare the concentrations of toxic heavy metals most commonly associated with poisoning of humans (lead, cadmium, manganese, copper, chromium, cobalt, nickel, and zinc) in the leaves and stems of Amaranthus hybridus (African Spinach) consumed from the study area.

Statement of problem

African Spinach is a widely consumed vegetable in Nigeria, and they are highly valued due to the quality and amount of nutrients and mineral elements they contain .The current high demand for leafy vegetables like A. hybridus in the cities and towns has stimulated the growth of market gardening along perennial rivers, streams and waste places rich in heavy metals in major towns and cities of Nigeria. Heavy metals are of great public health concern because of their non-degradable nature and their potential to accumulate in different parts of the body due to long biological half-lives. Most heavy metals are extremely toxic because of their solubility in water.

Research questions

This research was expected to answer the following research questions:

1. What is the magnitude of heavy metal contamination in leaves and stem of *Amaranthus hybridus* consumed in the study area?
2. How is the pattern of heavy metal distribution in the leaves and stem of the plant?
3. What are the likely implications on public health?

Hypothesis

Null Hypothesis (H0)

Heavy Metal concentration in samples of Amaranthus hybridus analyzed are within acceptable limits as set by the Joint FAO/WHO Expert Committee on Food Additives and the Agency for toxic substance disease registry (ATSDR).

Alternate Hypothesis (H1)

Heavy Metal concentration in samples of Amaranthus hybridus analyzed are above acceptable limits as set by the Joint FAO/WHO Expert Committee on Food Additives and the Agency for toxic substance disease registry (ATSDR).

Scope and limitations

This study considered only 8 of the many heavy metals. In addition only 9, (3 in each senatorial district) of the 21 Local governments in Kogi state were covered due to security, inaccessibility and resource availability.

Review of literature

Although the use of *Amaranthus hybridus* by a significant proportion of the population is well established, a study published by the American Phyto pathological Society reported an increase in the use of the plant as a leafy-vegetable crop on the African continent (Blodgett and Swart 2002). The limited amount of rainfall in Northern Nigeria and the scarcity of rich soil that can support all year-round farming has compelled many growers of vegetables to site their farms close to areas such as gutters, drainage and polluted rivers which predisposes their produce to heavy metal and fecal contamination. A seasonal potential toxic metal content analysis of Yauri river bottom sediments in

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North Western Nigeria concluded that, based on the pollution load index (PLI) values calculated, the river is polluted with all the elements analyzed with elevated concentrations of some of the heavy metals which were both as a result of environmental pollution and natural causes (Yahaya *et al*.,2012). A study to assess the bioaccumulation of heavy metals in spinach sold at vegetable farms in Katsina, Nigeria, conducted using atomic absorption spectrometer VPG 210 model reported that cadmium was the heavy metal with the highest concentration, closely followed by chromium, and zinc. The result from the study revealed the following; Kofar Marusa site, cadmium 12.5±2.5mg/kg > chromium and zinc both had 4.7±0.62mg/kg, while Kofar Durbi site Zinc 13.2±4.21mg/kg > cadmium 12.5±2.5mg/kg > chromium 4.71 ± 0.62mg/kg. Similarly, at Kofar/Sauri, study site, Zinc had 13.2±4.21mg/kg > Cadmium 12.5± 2.5mg/kg > Chromium 4.71±0.62mg/kg. However, concentrations of heavy metals in the soil of the study sites show chromium had high mean value of 10.19±0.41mg/kg > Zinc 6.13± 0.87mg/kg > Cadmium 5.84±0.83mg/kg: Plant concentration factor (PCF) in the study ranges between 1.40-2.8Mg/l at K/Marusa for Cd, Cr and Zn, K/Durbi 0.45-2.11 and K/Sauri with 0.3-4.0 respectively, The study concluded that measures should be taken in order to prevent the discharge of untreated waste water by the factories nearby which could be the potential source of contamination of vegetable and soil in the farms (Abba and Ibrahim, 2017). A comparative assessment of some heavy metals in *Gongronema latifolium, Amaranthus hybridus, Talinum triangulare, Telfairia occidentalis ,Piper guineense*,and *Ocimum gratissimum* commonly used for making local dishes in Yenagoa metropolis, Nigeria reported that the concentration of cobalt, lead, and cadmium were below detection level while the concentration of other heavy metals in the vegetables ranged from 1.85 - 3.55mg/kg for copper, 1.63 – 14.98 mg/kg for zinc, 5.83 – 186.59 mg/kg for manganese, 8.12 – 31.72 mg/kg for chromium, 5.01 – 16.03 mg/kg for nickel and 307.60 – 1051.31 mg/kg for iron. Analysis of variance showed that there was significant variation ($P<0.05$) among the vegetables analyzed. The study also reported that the concentrations of the heavy metals in the vegetables were found to be below Food and Agricultural Organization/World Health Organization maximum limit with the exception of iron and chromium (Izah and Aigberua, 2017).

A similar study was carried out in two major highways in Lagos, South west Nigeria to determine the level of lead (Pb) and cadmium (Cd) contamination in *Amaranthus viridis.* The samples of the plant were collected at distances of 5, 10, 15 and 20 m from the roadside and analyzed for of lead (Pb) and cadmium (Cd). Levels of Pb and Cd in soil were found to be 47 to 151 mg kg-1 and 0.30 to 1.33 mg kg-1 (dry weight) respectively. Concentrations in leaves ranged from 68 to 152 mg kg-1 and 0.5 to 4.9 mg kg-1 (dry weight) for Pb and Cd, respectively. The pattern and distribution of these heavy metals deposition on the plant, as reflected by the plant concentration factor (PCF) values, indicates a decrease in concentration with increase in distance from the road. Heavy metal concentrations in *Amaranthus* cultivated on soils characterized by heavy traffic were significantly higher ($P \leq 0.05$) than those cultivated on the reference soil. These findings indicate that while the levels of metals in soil were within the critical limits, the range within the plant leaves were above the normal limit for plants suggesting that *Amaranthus* has a way of concentrating metals in their tissues and or that aerial deposition may be a major source of contamination (Atayese, *et al.,* 2008). *Amaranthus hybridus* is a plant with high affinity for heavy metals and as such could be easily contaminated. A study which analyzed the heavy metal uptake by two edible *Amaranthus* herbs grown on soils contaminated with Lead, Mercury, Cadmium, and Nickel was carried out to investigate the abilities of 2 species of the plant *Amaranthus hybridus* (green herbs) and *Amaranthus dubius* (red herbs) and measure their response and ability to accumulate and tolerate varying levels heavy metals in their roots and shoots. Both herbs (red and green) were grown in soil pots contaminated with three mixtures of Cd (II), Ni (II), Pb (II), and Hg (II). The control treatment for the experiment was plants grown in the absence of the heavy metals mixture. The distribution of Cd, Ni, Pb, and Hg in the plants roots, stems, and leaves were analyzed in two stages. The first stage was after 5 weeks of plant growth while the second stage was at 10 weeks of growth. In the red herbs, the Cd concentration in the leaves at the second stage was 150 ppm and was present in higher concentrations than Ni, Hg, and Pb. At the highest contamination level, while in the green herbs plant, the concentration of Hg was the highest in the root, i.e., 336 ppm at the first stage, while the level in the leaves was 7.12 ppm. The study concluded that both the green and red herbs species of

Amaranthus showed an affinity for Ni and Cd with moderate to high levels detected in the leaves, respectively (Chunilall *et al*., 2005). This affinity of the plant for heavy metal accumulation as reported by this study is very vital because it debunks the claim that long period of exposure time is required for sufficient bio accumulation.

The public health effects of heavy metals from food

The relationship between heavy metals and human health is well documented. A recent multi-medium analysis which evaluated the Human health risk assessment of heavy metals in soil–vegetable system reported that diet dominated the exposure pathways by which heavy metals in soil might cause potential harm principally through food-chain transfer. According to the study, the total non-cancer and cancer risk results indicates that the investigated arable fields near waste mining and industrial sites were not suitable for root and leaf vegetables in view of the high risk of elevated intakes of heavy metals and its corresponding negative effect on food quality and safety for local residents and surrounding communities. From the results, Chromium and Lead were the primary heavy metals posing non-cancer risks while Cadmium produced the highest cancer risk (Liu *et al.*,2013). Heavy metal toxicity has proven to be a major threat to human health and there are several risks associated with it. Despite many not having any biological role, the toxic effects of these metals remain persistent resulting in sub optimal functioning of the human body and other harmful effects. Heavy metals can sometimes interfere with metabolic processes or act as a pseudo element of the body. Metal toxicity depends on the dose absorbed, the route of exposure as well as the duration of exposure, i.e. acute or chronic. This can result in various disorders and can also lead to excessive damage to vital body organs due to oxidative stress induced by free radical formation (Jaishankar *et al*.,2014). A recent study which evaluated the impact of heavy metals on children reported that heavy metal exposure have negative effects on children's health including lower birth weight, lower Apgar scores, lower anogenital distance, lower current weight, lower hepatitis B surface antibody levels, higher prevalence of attention-deficit/hyperactivity disorder, higher DNA and chromosome damage and lower lung function. Heavy metals according to the study also influence a number of diverse systems and organs within a child's body, resulting in both acute and chronic effects on children's health. These effects ranged from minor upper respiratory irritation to chronic respiratory, nervous, cardiovascular, urinary and reproductive disease, including the aggravation of pre-existing symptoms and disease (Zeng *et al*.,2016).

A study conducted in China reported that the carcinogenic risk of heavy metals to children which were 30 to 200 times higher than the safe level (1.0×10^{-6}–1.0×10^{-4}), was traceable to Cr, As and Ni pollution which emanated from ingestion of locally produced food. The finding from this study also indicates that 85% of the concentration of most elements was also traceable to ingested food. (Cao *et al*., 2016).

In general, the health risk related to heavy metal exposure from vegetable is due to chemical reactivity of the ions with enzymes, cellular structural proteins, and membrane system. The specific target organs are usually those organs that accumulate the highest concentrations of the heavy metal in vivo. This is however, dependent on several factors which include the route of exposure and the chemical features of the metal i.e. its valiancy state, volatility, lipid solubility etc. (Mahurpawar, 2015) The target organs of heavy metal and corresponding clinical manifestations of chronic exposures are presented below:

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Clinical aspects of chronic toxicities

Heavy Metal	Target Organs	Clinical effects
Cadmium	Renal, Skeletal and Pulmonary	Proteinuria, Glucosuria, Osteomalacia, Aminoaciduria, Emphysemia
Chromium	Respiratory tract	Ulcer, Perforation of Nasal Septum, Respiratory Cancer
Manganese	Nervous System	Central And Peripheral Neuropathies
Lead	Kidneys, Blood, Brain	Hypertension, Renal impairment, Seizures Immunotoxicity and Toxicity to the reproductive organs
Copper	Gastrointestinal (GI) tract, liver, and kidney	Hematemesis, Hypotension, Melena, Coma, Jaundice Damage to liver and kidneys.
Zinc	Kidney, liver, bones, liver, and lungs	Anemia neutropenia, Impaired immune function and adverse effects on the ratio lipoproteins
Nickel	Lungs and upper respiratory tract	Chronic bronchitis, Reduced lung function, and Cancer of the lung and nasal sinus
Cobalt	The respiratory tract and the skin	Hearing and Visual impairment, Cardiovascular and endocrine deficits

Research methodology

Study area

This study was conducted in Kogi State, North Central Nigeria. The State is located at an elevation of 55 meters above sea level and its population is approximately 3,595,789. Its coordinates are 7°45'0" N and 6°45'0" E in DMS (Degrees Minutes Seconds) or 7.75 and 6.75 (in decimal degrees). Its UTM (Universal Transverse Mercator) position is KP55 and its Joint Operation Graphics reference (JOG) is NB32-01(Getamap, 2019) The area has a rainfall pattern which peaks between June and September although there is not much rainfall in Kogi all year long. The climate here is described as a local steppe climate and classified as BSh by the Köppen-Geiger system. The average temperature in Kogi is 26.8 °c (Climate-Data, 2015) The average rainfall annually ranges from 1200 to 1500 mm while the vegetation of the area consists of rain forest on the eastern and typical wood land savanna and grassland to the central and western part of the state. The nature of soils in this area is mainly sandy loam, loamy sand and ultisol. [24] Kogi State has two main rock types, namely, the basement complex rocks of the Precambrian age in the western half extending slightly eastwards beyond the lower Niger Valley and the sedimentary rocks in the eastern half (Emurotu and Onianwa, 2017).

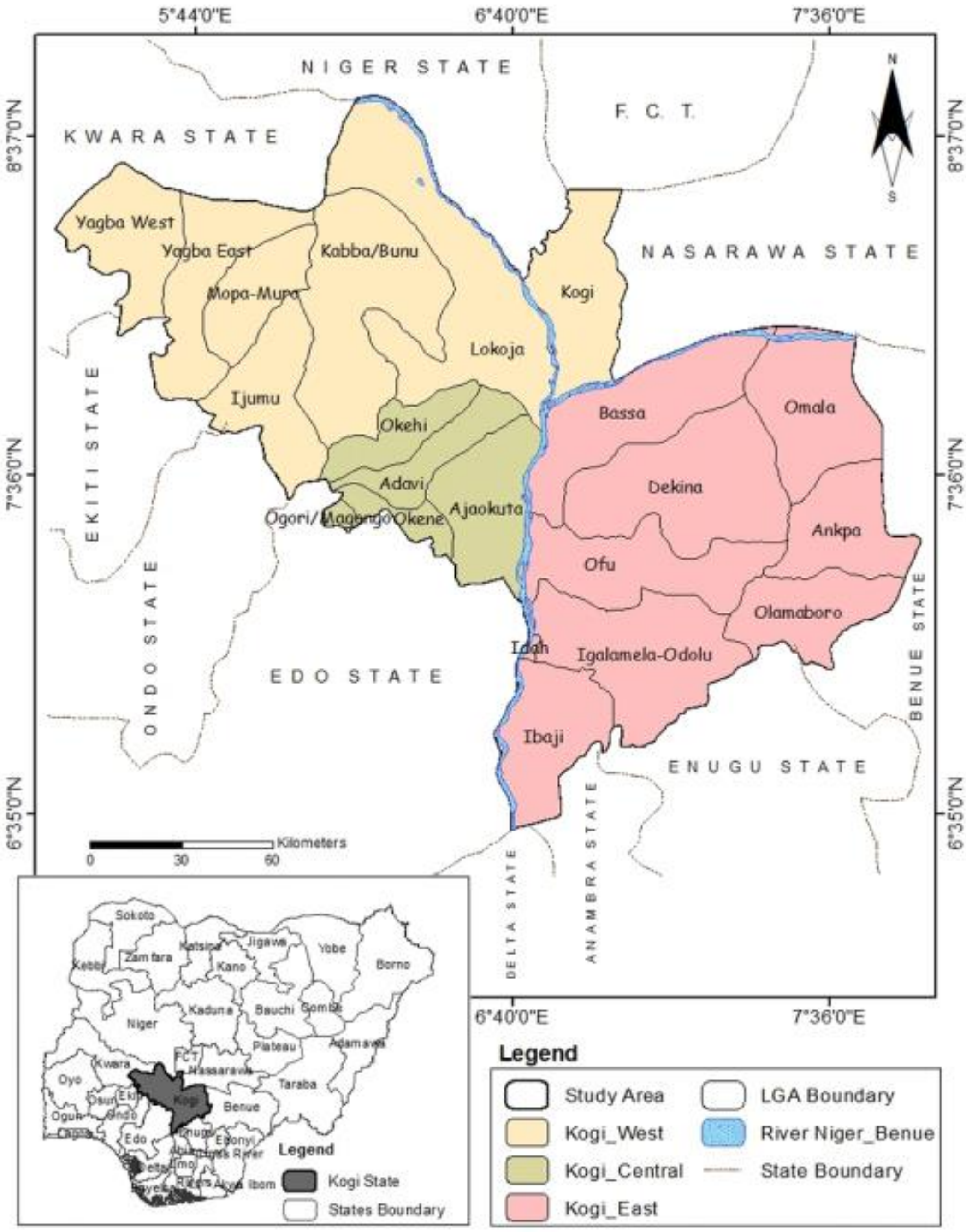

Figure 1. Map Showing the 3 Senatorial Districts of Kogi State and the Local Government Areas (Getamap, 2019)

Research design

The research design employed is as described by *Atayese et al* for the determination of total metal content in plants. The plants were divided into leaves, and stems. The samples were weighed to determine the fresh weight and then dried in an oven at 60° C for 48 hours. The dry samples were then crushed using a porcelain mortar and the resulting powder neatly packed in sample containers for onward `analysis for the heavy metals (Atayese, *et al.*, 2008).

Quality assurance

In order to prevent samples from being contaminated from secondary sources, the applicable quality control and assurance measures were put in place from the point of sampling to ensure the

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reliability of the results. Samples of the plant were also carefully handled to avoid cross-contamination. Glassware and containers used during this research were properly cleaned, and the reagents used were of analytical grades. In addition, deionized water was employed throughout the study and reagent blank determinations used to apply corrections to the instrument readings (Elbagermi *et al.*, 2012)

Sampling technique

Samples of the plant were collected from three major markets in the three senatorial districts using simple random sampling. On a major market day, all *Amarantus hybridus* sellers were informed about the study and their consent obtained. Pieces of paper with NO and a single YES corresponding to the total number of seller's present were written, well shuffled and shared amongst the sellers. The *Amaranthus* of the person who picked YES was picked for processing and analysis. The same procedure was adopted three times in selecting three markets from the list of major market list obtained in each senatorial zone.

Data collection instrument

Atomic Absorption Spectrometry (AAS) determines the presence and concentration of metals in liquid samples. When they are excited by heat in their elemental form, heavy metals will absorb ultraviolet light. Each heavy metal has a unique wavelength that will be absorbed. The Atomic Absorption Spectrophotometer looks for a particular metal by focusing a beam of uv light at a particular wavelength through a flame and into a detector (García and Báez 2012).

Validation of data collection instrument

Atomic Absorption Spectrometry (AAS) is the most widely recommended instrument utilized in analytical procedures for heavy metal. It is a validated, simple, reliable, sensitive and convenient method for quantitative estimation of trace metals and heavy metals in dried vegetables (Rawar, and Rohman2016) (Sharma *et al*.,2009). Standard solutions were frequently run to check the sensitivity of the instrument and the operation conditions used to operate AAS instrument were as recommended by the manufacturer.

Sample processing

Approximately 0.5 g of the powdered *Amaranthus hybridus* was transferred to a 25 ml conical flask; 5 ml of concentrated Tetraoxosulphate (VI) Acid (H_2SO_4) was then added followed by 25 ml of concentrated Nitric acid (HNO_3) acid, and 5 ml of concentrated hydrochloric acid (HCl). The contents of the tube were then heated at 200° C for 1 hour in a fuming hood, and then cooled to room temperature. After this, 20 ml of distilled water was added and the resulting mixture filtered using filter paper No.1 (11cm) to complete the digestion of organic matter. Finally, the mixture was transferred to a 50 ml volumetric flask, filled to the mark, and let to settle for at least 15 hours. The resultant supernatant was thereafter analyzed for heavy metal using atomic absorption spectrophotometer Model No: AAS- 6800N Shimadzu at National Research Institute for Chemical Technology (NARICT) Zaria Nigeria (Atayese, *et al.*, 2008).

Results

Table 1. Standard conditions for AAS: atomic absorption spectrophotometer

Heavy Metal n	λ (nm)
Cadmium	228.8
Chromium	357.9
Copper	324.8
Cobalt	240.7
Lead	283.3
Manganese	279.5
Nickel	232.0
Zinc	213.9

NARICT (2019).

Table 2. Maximum permissible limits for heavy metals in vegetables

Description	Cd	Cr	Cu	Co	Pb	Mn	Ni	Zn
FAO/WHO *Committee* of the *Codex Alimentarius Commission*	*0.1*	*2.3*	*40.0*	-	*0.3*	*500*	*1.5*	*0.6*
Agency for toxic substance disease registry (ATSDR, 1994				*0.05-*	*0.1*	-	-	-

Sources: FAO/WHO Committee of the *Codex Alimentarius Commission* and Agency for toxic substance disease registry (ATSDR*) 1994.*

Table 3. Analysis for cadmium

Sample (ppm)	**Actual Concentration in Leaves**	**Actual Concentration in Stem**
West 1	0.0002	0.0015
West 2	0.0008	0.3348
West 3	0.0032	0.2753
East 1	0.1911	0.0082
East 2	0.0784	0.0065
East 3	0.0284	0.0086
Central 1	0.0068	0.0007
Central 2	0.0028	0.0022
Central 3	0.0014	0.0020

Table 4. Sample analysis for chromium

Sample Stem (ppm)	**Actual Concentration in Leaves**	**Actual Concentration in Stem**
West 1	0.1574	0.1332
West 2	0.6911	0.0776
West 3	0.7130	0.0063
East 1	0.0851	0.0701
East 2	0.0434	0.1043
East 3	0.0467	0.0165
Central 1	0.0707	0.0420
Central 2	0.0414	1.3789
Central 3	0.0302	0.1255

Table 5. Sample analysis for chromium

Sample (ppm)	**Actual Concentration in Leaves**	**Actual Concentration in Stem**
West 1	0.0002	0.0163
West 2	0.0003	0.0209
West 3	0.0114	0.0242
East 1	0.0247	0.0066
East 2	0.0239	0.0033
East 3	0.0241	0.0018
Central 1	0.0183	0.0187
Central 2	0.0194	0.0171
Central 3	0.0190	0.0167

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Table 6. Sample analysis for cobalt

Sample	Actual Concentration in Leaves	Actual Concentration in Stem (ppm)
West 1	0.1498	0.1572
West 2	0.1237	0.1470
West 3	0.1289	0.1636
East 1	0.3168	0.3374
East 2	0.3719	0.3487
East 3	0.3070	0.3104
Central 1	0.3378	0.3341
Central 2	0.3232	0.3328
Central 3	0.3369	0.3243

Table 7. Sample analysis for lead sample

Sample (ppm)	Actual Concentration in Leaves	Actual Concentration in Stem
West 1	0.0666	0.1110
West 2	0.1296	0.1384
West 3	0.0412	0.1473
East 1	0.0137	0. 1317
East 2	0.0401	0.0311
East 3	0.1085	0.0144
Central 1	0.0708	0.0402
Central 2	0.0140	0.1516
Central 3	0.1608	0.1683

Table 8. Sample analysis for manganese

Sample	Actual Concentration in Leaves	Actual Concentration in Stem
West 1	0.0124	1.3810
West 2	0.0014	1.3891
West 3	1.3726	1.4050
East 1	1.4090	2.2339
East 2	2.1933	2.2688
East 3	2.2192	2.0609
Central 1	2.0565	0.1494
Central 2	0.0007	0.1482
Central 3	0.0250	0.1532

Table 9. Sample analysis for nikel

Sample	Actual Concentration in Leaves	Actual Concentration in Stem (ppm)
West 1	0.0089	0.0171
West 2	0.0217	0.0277
West 3	0.0294	0.0140
East 1	0.0076	0.0087
East 2	0.0221	0.0048
East 3	0.0352	0.0158
Central 1	0.0120	0.0033
Central 2	0.0433	0.0066
Central 3	0.0062	0.0172

Table 10. Sample analysis zinc

Sample	Actual Concentration in Leaves	Actual Concentration in Stem (ppm)
West 1	0.1874	0.3451
West 2	0.2073	0.0643
West 3	0.3501	0.0364
East 1	0.0015	0.0013
East 2	0.0255	0.0011
East 3	0.0013	0.0006
Central 1	0.0003	0.0020
Central 2	0.0013	0.0041
Central 3	0.0030	0.0025

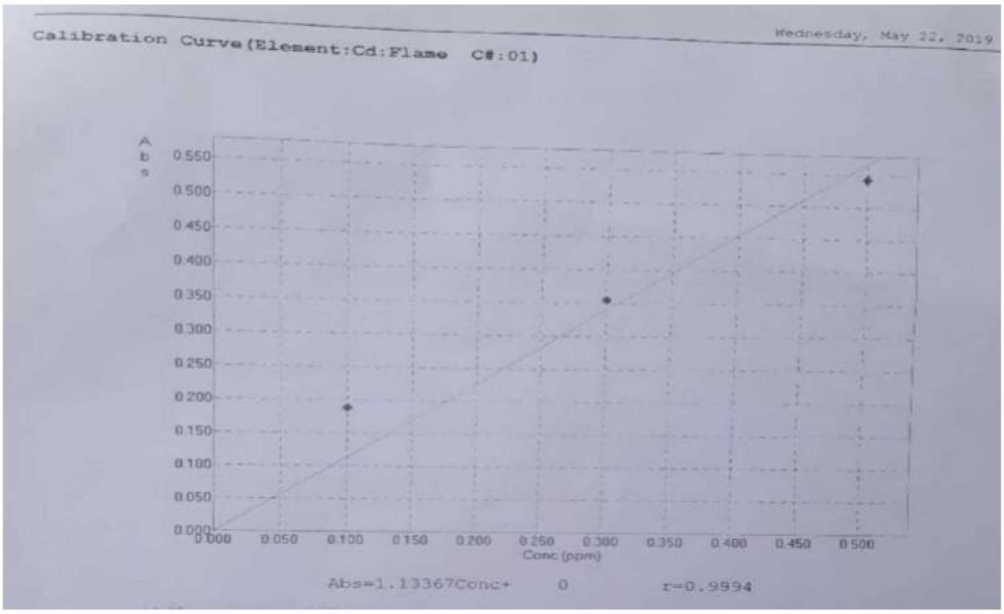

Figure 2. Showing the Calibration Curve of Cadmium

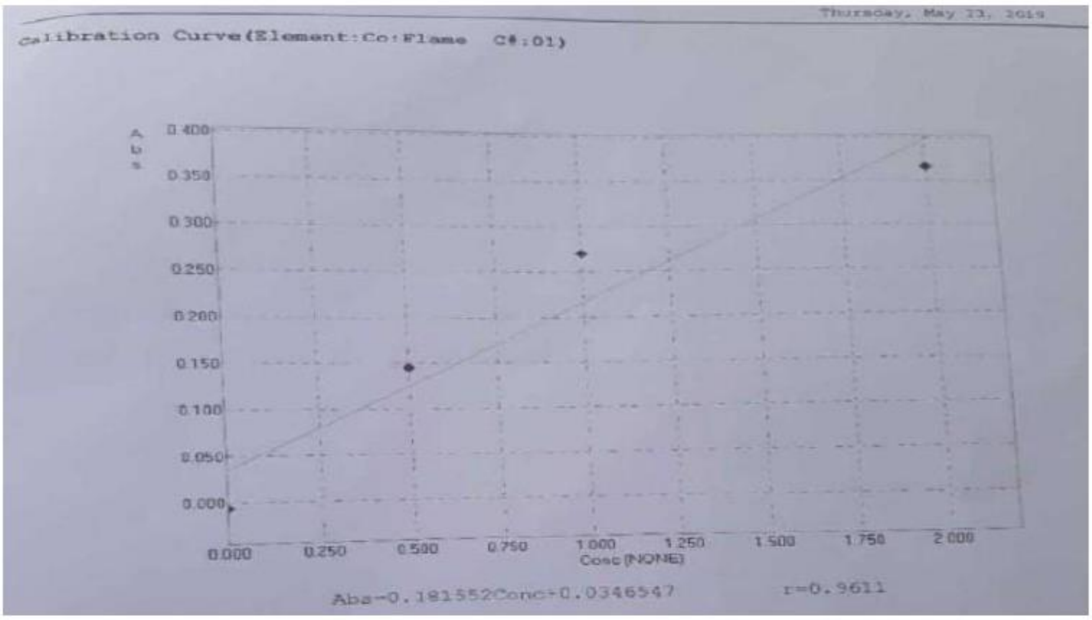

Figure 3. Showing the Calibration Curve of Cobalt

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Discussion

With the exception of Cadmium and Cobalt two heavy metals of public health importance, the results of the analysis for heavy metals using atomic absorption spectrophotometer were within set limits. The results show that while all values were within acceptable limits for Cadmium in the leaves, Cd was found in the stem sample in the western senatorial zone at a range of 0.007 to 0.3358 ppm above the FAO/WHO maximum limit of 0.1ppm (Tasrina *et al*.,2015). This finding agrees with the results of a study on heavy metal contamination of *Amaranthus* grown along major highways in Lagos which reported that the concentration of Cd in *Amaranthus* stem were highest at 4.0 ppm (Atayese, *et al.*, 2008). This also aligns with the results of another study on heavy metal uptake and accumulation by edible leafy vegetable *Amaranthus* hybridus grown on urban valley bottom soils which reported that uptake and accumulation of Cd was higher in the stem of the plant as compared to the leaves, the study reported 0.38 to 1.20 ppm for leaves and 0.6 to 2.5 for stems (Oluwatosin *et al*.,2009). However, this is in contrast with a study published in the *International Journal of Current Research* on the heavy metal (Pb, Cd, Ni, Fe and Zn) concentrations in soils and accumulation in Amaranthus Hybridus grown near solid waste dumpsites. The research reported that leaves rather than stems had higher concentration of Cd. (Eze,2014). This variation could be the result of the location of the study (dump site) as reported by the author.

The presence of Cobalt, another heavy metal of public health concern above the maximum permissible limit set by the Agency for Toxic Substance Disease Registry (ATSDR) is another major finding from this study. The maximum permissible limits for the heavy metals in vegetables set by (ATSDR) is between 0.05 to 0.1ppm 0.1ppm (Tasrina *et al*.,2015). The results indicate high levels of Co in the samples across all three senatorial districts with a concentration of range of 0.1289 to 0.3487 ppm in the leaves and 0.1470 to 0.3719 in the stems. This agrees with the findings of a study on the levels of heavy metals in leafy vegetables grown around waste dumpsites in Akure, Southwestern Nigeria which reported that the presence of Co in the shot of an *Amarathus* Spp ranged from 0.21 to 4.75ppm (Aiyesanmi and Idowu, 2012).

In contrast, another study conducted in Tanzania reported a slightly different result which indicates that cobalt was only found in the roots at an average concentration of 0.14 ppm but was undetectable in the edible parts (Stem and leaves) of plant (Sahu and Kacholi, 2016). This variation could be due to natural and anthropogenic factors, the accumulation and distribution of heavy metals in the plant depend on the plant species, the levels of the metals in the soil and air, the element species and bioavailability, pH, cation exchange capacity, climacteric condition, vegetation period and multiple other factors as reported by (Filipović-Trajković,2012).

Conclusion

The potential consequences of exposure to harmful substances, on either a population or an individual basis, is a fundamental concern in epidemiology and public health. According to the World Health Organization (WHO), Cd exerts toxic effects on the kidney, the skeletal and the respiratory systems, and is classified as a human carcinogen, as a result, exposure to high levels of this metal over a short period of time can result in flu-like symptoms and can damage the lungs while chronic exposure to low levels over an extended period of time can result in kidney, bone and lung disease. (WHO,2019) The presence of this metal above the FAO/WHO maximum permissible limit of 0.1ppm in the vegetable is a major public health concern because of its harmful nature and the large number of people who consume it especially the pregnant women who heavily rely on it for their iron needs.

Co on the other hand is one of the most important essential components for vitamin B12, it is beneficial for humans because it is essential for thyroid metabolism and the maintenance of human health. It is also used to treat different types of cancer and anemia However, absorbing large amount of cobalt over long period of time can result in serious health problems, such as: cardiomyopathy a condition where the heart becomes big and floppy and has problems pumping blood, it can also lead to hearing loss and other auditory problems.(Karpiuk *et al*.,2016). The presence of Co at a high of 0.3487ppm above the maximum permissible limit of 0.1ppm set by the Agency for Toxic Substance Disease Registry (ATSDR) in all three senatorial districts is another serious public health concern for food safety. As one of the most widely consumed vegetable in Nigeria and a staple food in a country of over 200 million the likely accumulation of Co in the body over a long period of time as a result of consuming vegetables high in Co can have far reaching public health implications which can further complicate the current public health crisis in Nigeria.

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