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Full Length Research Article

TRACE METAL CONTENTS OF VEGETABLES IN OGBEDIGBO AFOR, DELTA STATE, NIGERIA

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ABSTRACT
The study investigated the contents of trace metals (Pb, Cu, Zn, Cr and Fe) accumulated in five vegetables: *Talinum triangulare* (waterleaf plant), *Vernonia amygdalina* (bitter leaf plant), *Ocimum gratissimu* (scent leaf plant) and *Telfairia occidentalis* (fluted pumpkin) obtained from two different locations in Ogbedigbo Afor Delta State Nigeria, using Atomic Absorption Spectrophotometer (ASS) based on dry weight of the vegetables. The results of the trace metal contents in the vegetables ranged as follows: Pb (2.642-3.30 mg/kg), Cu (0.377- 0.864mg/kg), Zn (0.377mg/kg to 0.864mg/kg), Cr (<0.001-0.007mg/kg) and Fe (16.9-25.16mg/kg). The amount of Zn, Cu, Fe and Cr detected in all vegetables are typically lower than the FAO/WHO permissible thresholds while Pb concentration were significantly above these guidelines. Statistical analysis of trace metal concentration in *Talinum triangulare, Vernonia amygdalina Ocimum gratissimu* and *Telfairia occidentalis* from the two locations, samples indicated significant differences in Pb, Cu, Zn, Cr and Fe concentration with Zn and Fe showing maximum bioconcentration in all samples. The bioconcentration of Cr and Pb even at minimum accumulation within safe limit of FAO/WHO endangers locals who frequently eat these vegetables. Thus, governmental agencies must regulate and constantly monitor anthropogenic actions to decrease hazardous metals undue accumulation in the ecosystem food sequence. The study has a great implication in environmental monitoring and management.

Keywords: Trace Metals, Bioconcentration, Accumulation, Anthropogenic Actions, Environmental Management.

INTRODUCTION

In different parts of the globe, researchers have reported that anthropogenic actions have facilitated the accumulation of trace metals into the environment which have negatively changed the components of the ecological system and threatened the health of mankind (Khan *et al.,* 2010; Nirzabeygi *et al.*, 2017; Naseri *et al.*, 2021; Agbogidi et al., 2024; Bankole *et al.*, 2024; Wan *et al.*, 2024). Human activities like rapid industrialization by natural resource exploration and exploitation, urban expansion through construction of building, roads and alteration land use, deforestation, bush burning, vehicle emission and motor-tyre burning lead to accumulation of trace metal in the soil. Khan *et al.*, (2010), long-established that soil primary absorbs the released pollutants from the aforementioned human actions. The study of Edo *et al.* (2024) maintained that plants assimilate these metals in the contaminated soil with their roots. Overtime, these trace metals bioaccumulated in the plant tissues becomes bioconcentrated and poisonous to those in the higher trophic levels.

Vegetables are staples that contains essential micronutrients and have the capacity to bioaccumulate toxic metals from the environment (Chauhan *et al.*, 2014; Onakpa *et al.*, 2018; Oni and Abiola, 2019). Vegetable can be a source of Fe and Zn to children or adult having its deficiency as they pose no threat when within the limit of FAO/WHO (2001). Conversely, the availability of non-essential metals like Cr, and Pb found in vegetable undermine the safety of those who consume them even at minimum concentration. Iyama *et al.* (2022) asserted that Pb found in vegetable in Port Harcourt Metropolis, Nigeria put consumers at the risk of having cancer. Recent study of Alege *et al.* (2025), investigated vegetables collected from three farming sites in Kumasi, Ghana and found out that they bioaccumulated Pb and Cr which have potentials of causing cancer in children. Yahaya *et al.* (2020) highlights the necessity for safety assessments with the possible role of noxious metals contamination in edible vegetable crops play different role in rising chronic diseases in developing countries.

Considering the intense industrial activities, urbanization and uncontrol waste disposal in Delta State and the health dangers that trace metal pose to consumers of these vegetables, assurance of food quality becomes very important. It is in this regard, this study aims to investigate trace metal content in vegetables in Ogbedigbo Afor, Delta State, Nigeria. The findings from this study would assist policymakers and governmental agencies to take necessary decision and it will serve as a primary data for further studies..

MATERIALS AND METHODS

Study Area

The study was carried out in Ogbedigbo a village in Afor clan that geopolitically located in Ndokwa-East Local Government Area (LGA) of Delta State, Nigeria. Geographically, the area is located 5°47'12.4692N Latitude and 6°27° 34.8048"E that lies within tropical rainforest zone of South-South Nigeria. The soil within this area is characterized with loamy and sandy soil in the residential area and clay in the river area with river bodies towards it has common boundaries with Ogbe-Ani on the north, Osissa on the south, Onitcha-Ukwani on the west, Okpai and Onuaboh on the east. The chief occupation of the natives is farming and fishing. However, the area is characterized by the operation of crude exploitation and exploration companies and building construction which is proximate to where the vegetables are cropped in both the residential and river area. These activities make it very suitable to evaluate trace metal contents in the cropped vegetables in the area.

Sample collection

The vegetable sample in this research were collected from farms in Ogbedigbo Afor, Delta State, Nigeria. The farms are privately

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owned by locals from the community. The vegetables sampled are commonly consumed in the daily meal of the locals and reflect the commonly grown varieties of leafy over-ground in the area. The leafy vegetables were collected from two different areas based on availability: vegetable species such as *Talinum triangulare*, *Vernonia amygdalina* and *Ocimum gratissimu* were systematically obtained from farms in the residential area whereas, *Telfairia occidentalis* sample was collected from the farm across the river area which is a major farming area (Table 1).

The collected samples were properly packed and stored in different labelled polyethene bags accordingly and brought to the laboratory for preparation and treatment.

Table 1: Taxonomy of collected vegetables

S/N	Species name	Family	Common name
1.	*Vernonia amygdalina*	Asteraceae	bitter leaf
2.	*Talinum triangulare* (Jacq.) Willd	Portulacaceae	water leaf
3.	*Ocimum gratissimu* L.	Lamiaceae	scent leaf
4.	*Telfairia occidentalis* Hook.fil.	Cucurbitaceae	fluted pumpkin

Sample Preparation and Treatment

The collected leafy vegetable sample were thoroughly washed with sterile deionized H_2O. After washing, samples were cut into pieces with a sterilized knife, carefully air-dried for 7days and dried in the oven at 80oC for 48 hours to a constant weight without volatilization of trace metals following standard method for sample preparation (Tappi Test Method, 1989). The oven-dried samples were grinded with porcelain mortar and piston into fine powder (ash) and stored in a plastic container without humidity until they were digested.

Digestion of Plant A Samples and Determination of Trace Metals

To determine trace metal in the leafy-vegetable samples this study adopted digestion method Tappi Test Method (1989).

In order to digest the sample, fine powder(ash) of 2g was weighed into an unfilled digestion flask comprising 9ml of a concentrated acidic mixture of HNO_3, HCl, and H_2SO_4. A blank sample was organized by adding 9ml of the same acid mixture to another empty digestion flask. Both flasks were heated on an electric hot plate at 80-90°C for 30 minutes pending when the solutions boiled and became pure. After cooling, the product obtained from the reaction were filtered using Whatman No. 4 filter paper and quantitatively moved into volumetric flasks (100ml), each diluted with 50ml deionized water. The filtrate were investigated for trace metal contents. Atomic Absorption Spectrophotometer (ASS) was the instrument used to perform the investigation of trace metals in the filtrate to determine the presence of Copper, Chromium, Lead, Zinc, and Iron following standard protocols and procedures to guarantee the accuracy and reliability of the results.

Statistical Analysis

The results obtained were subjected to mean analysis while the level of significance across the various vegetable samples were done using the Duncan Multiple Range Test (DMRT).

RESULTS

The amount of trace metals differs among the sampled vegetables and the concentration of Iron, Lead , Zinc, Chromium and Copper within the samples is presented in Table 2. The level of Pb present in the different vegetables range between 2.642mg/kg to 3.30mg/kg, Cu range between 0.377mg/kg to 0.864mg/kg, Zn range between 20.06mg/kg to 32.73mg/kg, Cr range between <0.001 mg/kg to 0.007mg/kg, Fe is present within the range of 16.93mg/1 to 25.16mg/kg. Means with different letter superscript within the same column showed a significant difference in concentrations of metals ($P < 0.05$) by means of the Duncan multiple range tests (Table 3). The result indicate bioconcentration of Zn and Fe were in high amount in all the sampled vegetable whereby the concentration of Cr is lower in all samples.

Table 2: Qualitative result of trace metals in vegetable samples obtained from Ogbedigbo Afor, Delta state, Nigeria

	Trace metals				
Vegetable Sample	Chromium	Copper	Zinc	Iron	Lead
Vernonia amygdalina	+	+	+	+	+
Talinum triangulare	+	+	+	+	+
Ocimum gratissimu	+	+	+	+	+
Telfairia occidentalis	+	+	+	+	+

Positive(+) detected; Negative(-) not detected

Table 3: Trace metal concentration of vegetables obtained from Ogbedigbo Afor, Delta state, Nigeria

		Vegetable Sample				
S/N	Trace Metals(mg/kg)	*Vernonia amygdalina*	*Talinum triangulare*	*Ocimum gratissimu*	*Telfairia occidentalis*	FAO/WHO permissible limit in Vegetables(mg/kg)
1.	Pb	2.902^a	3.274^a	3.051^a	2.642^b	0.3
2.	Cu	0.377^a	0.486^a	0.864^b	0.678^{bc}	73.3
3.	Zn	24.352^a	32.739^a	20.064^b	22.732^c	99.4
4.	Cr	0.002^a	0.007^b	$<0.001^c$	$<0.001^c$	1.3
5.	Fe	25.162^a	24.304^a	16.930^b	24.982^a	425.5

Means with different letter superscript within the same column showed a significant difference in concentrations of metals ($P < 0.05$) by means of the Duncan's Multiple Range Tests

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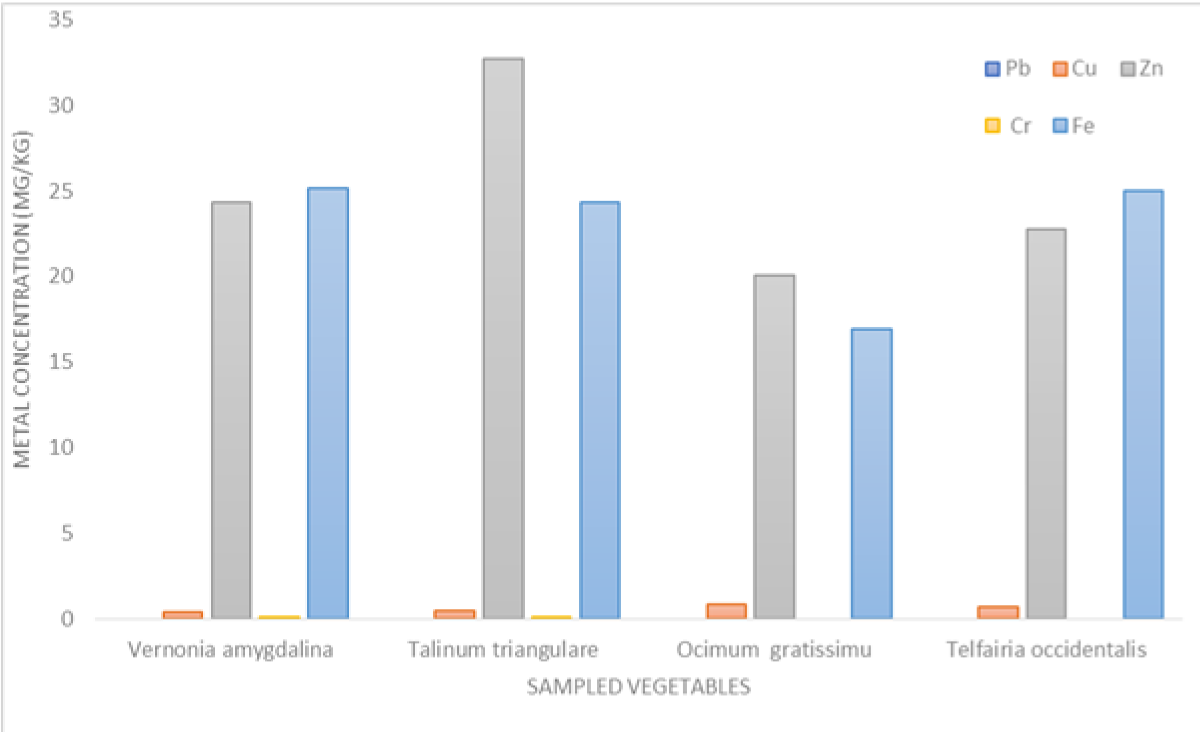

Fig 1: Trend of trace metals (in mg/kg) contents in Vegetables Sampled

DISCUSSION

Trace metals such as Fe, Cu and Zn are reported to be vital in human metabolic process when they are not exceeding the standard of wellbeing established by the FAO/WHO (Dagne and Endale, 2019; Sandeep *et al.,* 2019; Onakpa *et al.,* 2018), whereas Cr and Pb are hazardous trace metal even at lower amount (Ullah *et al.,* 2017). Various scholars have documented the harmful effect of Pb, Cu, Zn, Cr and Fe (Dagne and Endale, 2019; Naseri *et al.,* 2020; Cheraghi *et al.*, 2024). The effects have been reported to distort development and growth in plant (Islam and Hoque, 2014; Onakpa *et al.,* 2018; Mawari *et al.,* 2022). Besides, high concentration of trace metals in vegetables can result to significant inhibition of germination, photosynthesis functions, respiration, transpiration and alteration in nutrient homeostasis and reduction in the ratio of shoot and biomass (Islam and Hoque, 2014; *Dixit et al.,* 2015; Kumar *et al.,* 2015).

During this research, the concentration of Pb was available in all sampled vegetables with *Talinum triangulare* having highest value of 3.274 mg/kg while the lower concentration of Pb was observed in *Telfairia occidentalis* 2.642 mg/kg. The concentration of Pb investigated is similar to the study of Obi-Iyeke (2019), evaluated heavy metals in fruits and vegetables in Delta State. Conversely, the study of Islam *et al.,* (2019) reported high concentration of Pb whereas the study of Oni and Abiola (2019) documented lower concentration. The value of Pb in this study surpasses the maximum threshold as proscribed in FAO/WHO which is 0.3mg/kg. The presence of Pb in the vegetable indicates that the soil which its farmed is contaminated. This assertion inclines to the finding of Islam *et al.,* (2019) and Bankole *et al.,* (2024). Bankole *et al.*, (2024) evaluated heavy metal from soils collected from Ihwrekreka town in Delta State using plasma mass spectrometry and their evidence highlights that crude oil activities increased concentration of Pb in soil, as it is the primary metal that is contributing to hazardous index value of the people with Pb found above the permissible level recommended by WHO. Toxicity of Pb in plants includes inhibition of metabolic process of growth and development (Aponte *et al.,* 2020) and in animals its result to brain disorder and kidney complications that can result to death (Nas and Ali, 2018).

Concentration of Cu in all vegetables ranged from 0.377-0.864 mg/kg as shown on Table 2 and within the permissible level of FAO/WHO. *Ocimum gratissimu* accumulated highest content of Cu with 0.864 mg/kg. This quantity of Cu in the vegetable indicate that vegetable is rich in copper which is essential for humans and can be supplement for meal deficient of Cu as it has properties of co-enzyme (Mirzabeygi *et al.*, 2017; Blumberg *et al.,* 2017). However, when copper level exceeds the require limit and it is consumed by humans through their meals it can result to anemia, neutropenia, bone abnormalities, hypopigmentation, osteoporosis (Onakpa *et al.*, 2018; Obinna and Enyoh, 2019; Chiou *et al.,* 2019). Soil heavily polluted with copper from anthropogenic incursion on a farmland can bioaccumulate in the plant and cause leaf discolouration and challenge to uptake essential nutrient from the soil (Kananke *et al.*, 2016; Rahmdel *et al.,* 2018).

In this study, Chromium (Cr) concentration in all sample did not exceed the recommended range of FAO/WHO. Its slightly present in all vegetables and highest concentration of 0.007mg/kg was

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observed in *Talinum triangulare* which is lower compared to the report of Noro *et al*., (2023) who evaluated poisonous metals in green vegetables in Lagos, Nigeria. Findings of this study varies with Hannah *et al*., (2016). Hannah *et al.,* (2016) documented that the content of Cr in vegetables obtained from four different markets in Lagos Metropolis ranges 0.25-1.15mg/kg which pose more threat to consumers within that area. Oil pollution from crude exploration, dumping of electronic waste on the farmland and uncontrolled use of pesticides by farmers can attribute to influence the bioavailability of Cr in the vegetables, this corroborates with the findings of Sharma *et al*., (2020) and Kapour and Singh (2021)
Fe was observed in all samples and the value were below the required threshold by FAO/WHO. The highest content was observed in *Vernonia amygdalina* with 25.162mg/kg. Comparatively, the result of Ogundele *et al.*(2019) showed higher Fe concentration in *Telfairia occidentalis, Ocimum gratissimu* and *Talinum triangulare.* Several publications have reported that Fe deficiency is a global concern (Hassan *et al*., 2016; Stuetz *et al*., 2019; Mwangi *et al*., 2021). Prior investigation by Yahaya *et al*., (2020) revealed that Fe is very abundant in Nigeria soils. This is the reason why iron is reported to be present in all sampled vegetable. This indicate that the sample from this current study is safe for consumption and can be a good source of Fe which is an essential component of red blood cell in humans (Adu *et al*., 2014; Dagne and Endale, 2019; Gupta *et al.,* 2022).

The content of Zn was available in all vegetable analyzed ranging from 20.06mg/kg to 32.739mg/kg, with *Talinum triangulare* observed to have maximum concentration of Zn among the samples (Fig. 2). The level of Zn bioaccumulation in this study is within recommended standard of FAO/WHO. Hannah *et al*., (2016) finding showed a similar range in the content of Zn (4.21-20.80mg/kg) in their sampled vegetable. Contrariwise, the level of Zn in this research was higher than result of Oni and Abiola (2019) that range from 1.36-5.87mg/kg. Zn is a vital micronutrient that is beneficial to mankind, coenzyme that involves in cell formation and growth, improve immunity and pH regulation. This finding poses an advantage for natives to consume these vegetables especially those have health issues related deficiency in Zn.

The vegetables collected from farms in Ogbedigbo Afor, Delta state are *Vernonia amygdalina, Talinum triangulare, Ocimum gratissimu* and *Telfairia occidentalis.* The findings disclosed that *T. triangulare* bioaccumulates high level of Zn and Pb, while *V. amygdalina* bioaccumulated more Fe. The Duncan's Multiple Range Tests (DMRT) equally revealed that trace metals like Zn, Fe and Pb were very significantly bioaccumulated in the various investigated vegetables from the farms (Table 2). Additionally, Zn, Fe, Cr and Cu were below the FAO/WHO safe limit except for Pb (Table3).
Vegetables accumulate these trace metal from different activities of mankind. Crude oil exploration and exploitation actions within the Niger Delta region that leads to oil spill, gas flaring and vehicular emissions makes this trace metal available in the environment that bioaccumulate in vegetables farmed in this region (Udofia and Joseph, 2022; Agbogidi *et al.,* 2024; Akter *et al.,* 2024; Bankole *et al.*, 2024) Intensive agricultural and building construction activities have greatly influence distribution of trace metal in the environment (Ashraf *et al*., 2021; Wan *et al.,* 2024; Mawari *et al*., 2022). Dumping of household wastes on farmlands is another human negligence that aids the distribution of trace metals (Jordao *et al.*, 2006; Ashraf *et al.,* 2021). The toxicity of the bioaccumulation of Pb, Cu, Zn, Cr and Fe when consumed by man and animals is well documented by Balali-Mood *et al*., (2021), Guadie *et al.* (2021), Gupta *et al.*(2022) Edo *et al.*, (2024), and Bankole *et al*., (2024). This current study revealed that the vegetable studied appeared to have high concentration of Zn and Fe (Fig. 2). Although, Zn is reported by and to be essential in human diet and less toxic to humans.

In Delta State, inadequate monitoring of industrial activities, construction of building and release of domestic effluents have impacted the environmental that led to the bioavailability of toxic trace metal like Cr and Pb. The anthropogenic actions continue to pollute the soil which these vegetables anchor. From the current study, the vegetables analyzed may be of threat to consumers in the area as there is no safe level for trace metal particularly Cr and Pb (Hannah *et al*., 2016; Sharma *et al*., 2020; Kapour and Singh, 2021). Previous research of Obi-Iyeke (2019) reported absence of Cr in all fruit and vegetable in Delta State. On the other hand, recent publication of Omokaro (2025) which evaluated micronutrients and heavy metals in soils in Delta State reported the presence of Cr in the sediments of both the control site and dumpsites. This explains that as industrialization expands over years and negligence to strict compliance from agencies introduced trace metals that are toxic in low concentration becomes bioavailable that are bioconcentrated in the plants in Delta State. The study of Bankole *et al.* (2024) validates the high level of Pb found in this study, spurring the urgency to reduce activities that promote Pb in the soil and vegetable from Delta State as bioconcentrations of Pb in the biological consumption sequence compromising the safety of the people. Thus, it is recommended that adequate monitoring oil company activities and integrated management of by-products from construction sites, household effluent and other pollutants around farm area is important to minimise the health risk from consuming vegetables and other fruits.

Conclusion
The five trace metals analyzed (Cr, Cu, Zn, Pb and Fe) were bioavailable. Availability of these: Cu, Zn, Cr, Fe metals in all vegetable are below the recommended level by the FAO/WHO whereas Pb was significantly above the FAO/WHO advised level of safety in all vegetables. Pb toxicity is a great concern that these vegetables are frequently consumed by the native in large quantities which can expose them to terminal conditions. Severely low content of Cr in the sampled vegetables during this investigation, still posed an atom of threat as these vegetables consumed cannot offer assurance of safety to the in people Ogbedigbo Afor, Delta State and nearby communities if sold. For a reason that, trace metals are difficult to eject from the body of humans due to its cumulative effect. Environmental remediation and constant monitoring of the soil quality, status of biodiversity and harmful anthropogenic activities. Daily consumption of vegetables from close by farms are significant to numerous low-income families in rural communities like Ogbedigbo Afor, this can result to health issues related to trace metal ingestion. Thus, suitable procedures could be implored by government, policymakers and academic community to safeguard Nigeria rural communities with oil exploration activities.

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