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Seasonal Variation in Heavy Metal Concentration in Telfairia Occidentalis Leaves in Ibeno Local Government Area, Akwa Ibom State

Erienu Obruche Kennedy[1], Onwugbuta Godpower Chukwuemeka[2], Njor Oru Ogar[3], Clark Poro David[4], Alani Olubukola Anuoluwapo[5], Essiet Akanimo Gordon[6], Apuyor Kingsley Efe[7]

[1]Department of Chemistry, Delta State College of Education, Mosogar, Delta State, Nigeria
[2]Department of Biochemistry/Chemistry Technology, University of Port Harcourt, River State
[3]Department of Science Laboratory Technology, Federal Polytechnic, Ugep.
[4]Department of Chemical Science, Edwin Clark University, Kiagbodor, Delta State
[5]DK Olukoya Central Research Laboratory, University of Lagos, Akoka-Yaba, Lagos State
[6]Department of MLST, Federal College of Medical Laboratory and Technology, Jos, Nigeria
[7]Department of Chemistry, Dennis Osadebay University, Asaba, Delta State

Abstract- The concentrations of heavy metals in the Ibeno Local Government Area of Akwa Ibom State, Nigeria were examined. This study employed an experimental design methodology. In December 2024 and June 2025, fifteen composite samples of Telfairia occidentalis leaves were collected. The leaf samples underwent washing with de-ionized water, were dried to a constant weight in an oven at 105 °C, and then pulverized to achieve a 2 mm mesh size for subsequent analysis. The ground leaves were digested using 1.0 cm3 of concentrated HClO4, 5 cm3 of concentrated HNO3, and 0.5 cm3 of concentrated H2SO4 in a 50 cm3 Kjeldahl flask. The concentration of heavy metals was determined using Atomic Absorption Spectroscopy. The data were analyzed based on the first-order kinetic model InC = InCo - kt. The concentrations of heavy metals (mg kg-1) during the dry season were: Mn (7.73 ± 3.06), Fe (5.93 ± 1.28), V (0.16 ± 0.26), Cd (0.21 ± 0.16), Ni (0.02 ± 0.01), while during the wet season, they were: Mn (7.75 ± 3.76), Fe (5.96 ± 4.07), V (0.21 ± 0.09), Cd (0.19 ± 0.06), Ni (0.03 ± 0.06). The results indicated that the concentrations of heavy metals varied between the wet and dry seasons. The mean concentrations of certain heavy metals (Ni, V, Pb, Zn, and Co) in the leaves of Telfairia occidentalis fell within the acceptable range of WHO standards for vegetables and food products, with the exception of Cd, Fe, and Mn. In conclusion, Telfairia occidentalis can serve as a resident indigenous plant bioindicator for monitoring anthropogenic influences of V, Pb, Mn, and Zn in the soil of the study area.

Keywords- Telfairia occidentalis, heavy metals, Ibeno LGA, AAS

I. INTRODUCTION

Heavy metals, while not easily defined, are commonly referred to as a collective term for metals and metalloids associated with pollution and toxicity (Obruche et al., 2025). This category also includes certain elements that are essential for living organisms at low concentrations.Toxic metal is an

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alternative term for heavy metal, specifically denoting non-essential elements such as Pb, Cd, Hg, As, Ti, and U, while it is inappropriate for biologically essential elements like Co, Cu, Mn, Se, and Zn (Umudi et al., 2022; Akpoveta et al., 2024). The existing classification, which is somewhat ambiguous, is based on atomic density (76 gcm-3) but includes a highly varied group of elements, making it inadequate.

The phrase 'trace metal' is becoming increasingly popular as a replacement for heavy metals, although it has not yet gained widespread acceptance (Osuji & Chukwunedum, 2001; Umanah et al., 2025). In this study, the conventional term 'heavy metal' will be employed. Heavy metals are also classified as trace elements due to their presence in concentrations of less than 1%, often below 100 mg kg-1. Investigations into heavy metals within ecosystems have shown that many areas near urban centers, metalliferous mines, or major highways display unusually high levels of these elements (Abeokuta et al., 2025). Soils in these regions have been contaminated from various sources with Pb, Cd, Hg, As, and other heavy metals (Essiett et al., 2010). Nigeria may be confronting a silent epidemic of environmental metal poisoning due to the increasing quantities of metal waste released into the biosphere. Telfairia occidentalis, commonly referred to as fluted pumpkin, is part of the Cucurbitaceae family and is widely consumed in Nigeria, Ghana, and Sierra Leone. The local names for fluted pumpkin include Ubong in Ibibio and Ugu in Igbo.

This creeping vegetable grows low to the ground, characterized by lobed leaves and long, twisting tendrils. It is a warm-weather crop that thrives in lowland regions and can withstand elevations of a few meters above ground. It flourishes best in soils rich in organic matter. Plants grown within the heavy metals contaminated areas usually take up heavy metals by absorbing them from deposits on the part of the plants exposed to the air from polluted environments as well as from contaminated soil (Udo, 2006; Umudi et al., 2025). Several reports showed that heavy metals can accumulate in various plant tissues and cause membrane depolarization and acidification of the cytoplasm. Fluted pumpkin, commonly known as Telfairia occidentalis, holds considerable importance in the dietary needs of both humans and livestock (Umudi, 2011). It is a valuable source of protein, oil, minerals, and vitamins. The leaves are characterized by low crude fiber content yet are abundant in folic acid, calcium, zinc, potassium, cobalt, copper, iron, and vitamins A, C, and K. Additionally, it possesses medicinal properties; the leaves and seeds of fluted pumpkin can enhance hematological indices, improve sperm quality, and lower blood glucose levels (Okoh & Trejo-Hernandez, 2006). This plant is also rich in antioxidants, thiamin, riboflavin, and ascorbic acid.

The tender shoots and leaves of this vegetable are utilized in the preparation of various dishes in Southern Nigeria, including Edikang Ikong soup, a well-known dish among the Efiks and Ibibios in Cross River and Akwa Ibom States, Nigeria (Othman, 2001; Edema et al., 2009). It flourishes best during the early rainy season, typically planted between August and October. Telfairia occidentalis can be cultivated in gardens and has a lifespan of 3 to 4 years if adequate soil moisture is maintained. However, the roots of Telfairia occidentalis are thought to be toxic to humans if ingested. Studies have indicated that the leaves of fluted pumpkin plants grown in farmlands, away from major roads, do not accumulate significant levels of heavy metals such as Pb, Ni, Cd, Zn, Mn, and Fe. Nonetheless, environmental health scientists express concern regarding the potential bioaccumulation of heavy metals in the leaves of vegetables cultivated near heavily trafficked highways (Obruche et al., 2019). It is well-established that elevated industrial and traffic activities lead to increased concentrations of heavy metals in the environment, and plants in these regions are likely to absorb these metals either from the soil through their roots or from atmospheric pollutants through their leaves (Obruche et al., 2018; Ese et al., 2024).

Research conducted by Ukpong and Peter (2012) on the levels of Cd and Ni in vegetables from industrial regions of Lagos City, Nigeria, indicated that these areas exhibited elevated concentrations of Cd, Cu,

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and Ni in various edible vegetables compared to those found in residential zones. Additionally, the edible parts of five types of green vegetables, including Chinese cabbage, cowpea leaves, leafy cabbage, and pumpkin leaves, were sampled from multiple locations in Dar Es Salaam, East Africa, for analysis of Pb, Cd, Cr, Zn, Ni, and Cu. The findings revealed a direct positive correlation between the levels of Zn and Pb in the soil and those in the vegetables (Obruche et al., 2018; Ekpo et al., 2023; Umudi et al., 2025). Recently, the study area, specifically the Ibeno Local Government Area, has garnered attention due to the significant stress it has endured from both intentional and unintentional oil spills, blast water discharge, untreated sewage, gas flaring, and industrial effluents (Mughele et al., 2024; Ese et al., 2024). Currently, there is a lack of reports regarding the seasonal concentrations of anthropogenically associated heavy metals in Telfairia occidentalis (fluted pumpkin), a widely cultivated vegetable in the region (Udosen et al., 2012; Festus-Amadi et al., 2021).

This study aims to assess the seasonal concentrations of heavy metals in the leaves of Telfairia occidentalis within the Ibeno Local Government Area, Akwa Ibom State.

Figure 1: Sample of the studied plant *Telfeiria occidentalis* (fluted pumpkin)

II. MATERIALS AND METHOD

The study area

Ibeno Local Government Area encompasses a coastal region exceeding 1,200 square kilometers. It is positioned on the eastern side of the Niger Delta, which is a component of the Gulf of Guinea. This area is located at the southern extremity of Akwa Ibom State, situated between latitudes 7° 54′ and 4° 34′ North of the equator, and longitudes 7° 54′ and 8° 02′ East of the Greenwich Meridian (Umudi & Awatefe, 2018). The communities residing on the western bank of the Qua Iboe River lack access to the hinterland, relying solely on boats to navigate through rivers and creeks. The Qua Iboe River estuary, which falls within the coordinates of the study area, receives water from Douglas Creek (Ogwuche & Obruche, 2020).

This creek measures approximately 900 meters in length and 8 meters in depth. It serves as the conduit for the transfer of petroleum exploration and production (E and P) waste from the Exxon Mobil Qua Iboe Terminal (QIT) tank farm to the lower Qua Iboe River Estuary and adjacent creeks via two pipes, each with a diameter of 24 centimeters (Umudi et al., 2025). The Exxon Mobil oily sludge disposal site is situated next to this creek, and the flare stack, where gas is continuously flared, is also located in this vicinity. Several communities within Ibeno Local Government Area are positioned along the banks of the Qua Iboe River, while others are found along the Atlantic Littoral. Mkpanak, Ukpenekang, and Iwu-achang are situated on the eastern bank of the Qua Iboe River. In contrast, Okoritip and Ikot Inwang are located on the western bank, whereas Iwokpom-Opolom, Itak Abasi, Akete, and Okoritak are positioned along the Atlantic coastline. The Qua Iboe River estuary is in close proximity to the Exxon Mobil oil effluent treatment and discharge facility. Although the waste is released into the Atlantic Ocean, it may flow back into the estuary due to tidal movements (Onwerenmadu & Duruigbo, 2007).

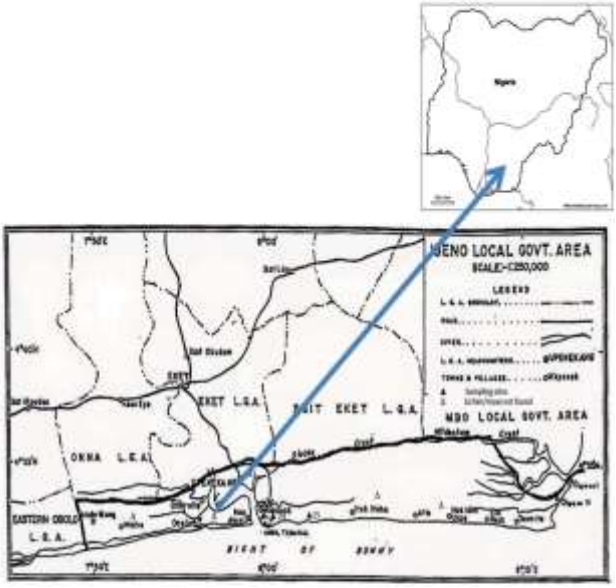

Figure 2: Map of the study area showing sampling locations

Sample collection

A random sampling technique was employed for the collection of fluted pumpkin leaves (WHO, 2010; Obruche et al., 2025). The leaves utilized in this research were gathered concurrently from 15 designated locations as outlined in the established sampling protocol. The selection of the plant species was predicated on its overall growth characteristics and its availability within the study area. Five replicate samples were obtained from each site. These five samples were subsequently combined to create a single composite sample. The leaves of the fluted pumpkin were severed using a stainless steel knife. The collected plant material was placed in a clean polyethylene bag, appropriately labeled, and stored in a cooler for transport to the laboratory for further analysis. The identification of the plant sample was conducted by the Department of Botany and Ecological Studies at the University of Uyo. The voucher specimens were archived at the herbarium of the Department of Plant Science and Biotechnology at the University of Nigeria, Nsukka (Obruche et al., 2019; Clark et al., 2025).

Preparation of Telfairia occidentalis (fluted pumpkin) leaf samples

The pretreatment method employed was based on the procedure outlined by (WHO, 2010; Erienu et al., 2022). The fluted pumpkin leaves were thoroughly washed under running water to eliminate any adhering soil particles and subsequently rinsed with distilled water to remove residual dirt. The samples were sun-dried to extract moisture. Following this, they were dried in an oven at 105 °C to achieve a constant weight, then pulverized into a fine powder using a laboratory mechanical grinder, and sieved through a 2 mm mesh size. The ground and sieved leaf samples were placed into labeled polyethylene bags and stored in desiccators.

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Digestion and Analysis

The methods employed for sample digestion were akin to those described by Ekpo et al. (2025), albeit with some minor adjustments. A quantity of two grams (2 g) of oven-dried, ground, and sieved sample was placed into a 50 cm3 Kjeldahl flask. To this, concentrated $HClO_4$,1 cm^3, HNO_3 (5 cm^3), and H_2SO_4 (0.5 cm^3) were introduced. The mixture was gently swirled and subjected to moderate heat, with the temperature gradually increasing. Digestion continued for approximately 15 minutes following the emergence of white fumes. After digestion, the mixture was allowed to cool. Subsequently, 10 cm^3 (10 cm^3) of de-ionized water was added. The resulting mixture was then filtered into a 50 cm3 volumetric flask and brought up to the mark with distilled water. A blank sample was created by repeating the same procedure, but without including the plant sample. Another blank sample was prepared using the same methods, excluding the sediment. The concentrations of Ni, V, Cd, Pb, Co, Fe, Mn, and Zn were determined using a Flame Atomic Absorption Spectrophotometer (AAS).

Statistical Analysis

The correlation coefficients (r) among the extractable heavy metals in sediment were evaluated using Pearson's Product Moment Correlation Coefficient (r), with the assistance of the Statistical

The concentrations of the eight Package for Social Science (SPSS).

III. RESULTS AND DISCUSSION

heavy metals (Ni, V, Cd, Pb, Mn, Fe, Co, and Zn) in leaf samples collected from 15 sampling sites within the study area, along with control samples, are presented in Tables 1 - 3, which correspond to the dry and wet seasons, respectively. The results are reported as mean±SD, % coefficient of variance (CV%), and standard deviation (SD).

Table 1: Concentrations (mg kg^{-1}) of heavy metals in leaves of *Telfairia occidentalis* for dry season.

Heavy Metal	HP_1	HP_2	HP_3	HP_4	HP_5	HP_6	HP_7	HP_8	HP_9	HP_{10}	HP_{11}	HP_{12}	HP_{13}	HP_{14}	HP_{15}	HP_C	Mean	SD	%CV	Mean±SD
Ni	0.04	0.03	0.03	0.03	0.03	0.02	0.01	0.03	0.03	0.03	0.03	0.03	0.02	0.03	0.025	0.01	0.02	0.01	49.02	0.02±0.01
V	0.09	0.01	0.04	0.04	0.02	0.01	0.02	0.01	0.03	0.03	0.70	0.11	0.45	0.11	0.78	0.02	0.16	0.26	16.80	0.16±0.26
Cd	0.04	0.10	0.13	0.03	0.44	0.40	0.07	0.03	ND	ND	ND	0.51	0.05	0.08	0.61	ND	0.21	0.09	103.50	0.21±0.09
Pb	0.04	0.01	0.04	0.03	0.05	0.01	0.04	0.03	0.03	0.02	0.02	0.03	0.02	0.02	0.01	0.01	0.02	0.01	70.20	0.02±0.01
Mn	5.40	6.77	5.39	5.46	7.46	5.40	6.79	5.02	4.40	5.20	12.99	10.99	11.8	10.99	11.78	5.56	7.73	3.06	36.60	7.73±3.06
Fe	4.03	8.10	5.98	5.40	6.89	6.85	5.98	6.76	6.89	7.10	6.84	5.09	4.96	4.06	4.03	0.05	5.93	1.28	21.60	5.93±1.28

Co	0.05	0.05	0.06	0.06	0.06	0.06	0.07	0.69	0.07	0.08	0.08	0.08	0.08	0.02	0.01	0.01	0.10	0.16	162.70	0.10±0.16
Zn	0.01	0.01	0.02	0.03	0.03	0.01	0.07	0.08	0.01	0.04	0.07	0.05	0.07	0.07	0.07	0.01	0.03	0.03	86.60	0.03±0.03

HP = Heavy metals in plant samples, HPC = Heavy metals in control plant samples, ND = Not detected

Table 2: Concentrations (mg kg^{-1}) of the heavy metals in leaves of *Telfairia occidentalis* during wet season

Heavy metal	HP_1	HP_2	HP_3	HP_4	HP_5	HP_6	HP_7	HP_8	HP_9	HP_{10}	HP_{11}	HP_{12}	HP_{13}	HP_{14}	HP_{15}	HP_c	Mean	SD	%CV	Mean ±SD
Ni	0.01	0.04	0.03	0.03	0.07	0.02	0.03	0.03	0.03	0.03	0.03	0.03	0.02	0.03	0.03	0.01	0.03	0.02	51.62	0.03±0.52
V	0.01	0.01	0.03	0.04	0.03	0.01	0.02	0.03	0.03	0.80	0.10	0.38	0.11	0.69	0.75	ND	0.21	0.30	143.07	0.21±0.30
Cd	0.04	0.10	0.15	0.03	0.44	0.40	0.07	0.03	0.01	ND	ND	0.51	0.05	0.08	0.61	ND	0.17	0.21	125.50	0.17±0.21
Pb	0.02	0.09	0.03	0.02	0.16	0.07	0.12	0.17	0.09	0.17	0.09	0.13	0.05	0.08	0.07	0.02	0.09	0.05	58.07	0.09±0.58
Mn	5.40	6.78	5.30	5.51	7.46	5.50	5.99	4.02	5.40	6.19	11.10	11.1	11.9	9.99	12.78	4.00	7.75	3.07	39.60	7.75±3.07
Fe	4.03	8.10	5.98	5.40	6.89	6.85	5.97	6.76	6.89	7.10	6.84	5.09	4.96	4.07	4.39	0.02	5.96	0.21	20.87	5.96±0.21
Co	0.03	0.04	0.05	0.04	0.05	0.07	0.06	0.07	0.07	0.07	0.08	0.08	0.08	0.01	0.01	ND	0.05	0.43	43.43	0.05±0.43
Zn	0.01	0.01	0.02	0.03	0.03	0.01	0.06	0.06	0.02	0.67	0.07	0.06	0.06	0.07	0.61	ND	0.11	2.03	202.80	0.11±2.03

Table 3: Average concentrations (mg kg^{-1}) of heavy metals during wet and dry seasons in leaves of fluted pumpkin with WHO standards

Heavy metals	dry season	wet season	Average concentrations for dry and wet seasons	WHO standard
Ni	0.02	0.03	0.03	1.0
V	0.07	0.21	0.11	1.0
Cd	0.21	0.20	0.20	0.1
Pb	0.02	0.09	0.06	0.1
Mn	7.73	7.75	7.74	6.0
Fe	5.93	5.96	5.94	4.8
Co	0.10	0.05	0.08	7.0
Zn	0.03	0.61	0.32	6.0

The observed trend in the distribution of heavy metal concentrations (mg kg-1) in the leaves of Telfairia occidentalis during both dry and wet seasons is as follows: Mn (7.73 ± 3.06) > Fe (5.93 ± 1.28) > V (0.16 ± 0.26) > Co (0.10 ± 0.01) > Cd (0.21 ± 0.16) > Zn (0.03 ± 0.02) > Ni (0.02 ± 0.01) > Pb (0.02 ± 0.01) for the dry season, and Mn (7.75 ± 3.76) > Fe (5.96 ± 4.07) > V (0.21 ± 0.09) > Cd (0.19 ± 0.06) > Zn (0.11 ± 0.07) > Pb (0.09 ± 0.15) > Co (0.05 ± 0.03) > Ni (0.03 ± 0.06) for the wet season (refer to Tables 9 - 11). The concentrations of heavy metals in fluted pumpkin samples were found to be greater during the wet season compared to the dry season.

This increase may be attributed to a rise in soil water levels, which enhances the assimilation and translocation of nutrients within the plant. The study revealed that the average concentrations of certain heavy metals analyzed fell within the acceptable range as outlined by WHO guidelines for heavy metals in vegetables and food products, as shown in Tables 1 & 2. Notably, the concentrations of Cd (0.21/0.20) mg kg-1, Mn (7.73/7.75) mg kg-1, and Fe (5.93/5.996) mg kg-1 for the dry and wet seasons, respectively, were exceptions. These values exceeded the recommended limits of Cd (0.1 mg kg-1), Mn (6.00 mg kg-1), and Fe (4.0 mg kg-1). Similarly, a study conducted by Udosen et al. (2012) indicated that the levels of heavy metals (Pb, Ni, Mn, Cd, and Zn) in fluted pumpkin from the study area were significantly above the recommended thresholds. Heavy metals can adversely affect the nutritional quality of agricultural products and pose harmful effects on human health.

The variations in the concentrations of heavy metals in the leaves of fluted pumpkin across different seasons may be attributed to the compositions of the soil and the rate at which the plant absorbs minerals (Onwerenmadu & Duruigbo, 2007).

Seasonal Dynamics of Individual Element in Study Area.

Nickel (Ni)

The mean±SD (0.0221±0.0108 mg kg-1) and % CV (49.015 %) of Ni were observed in the leaves of Telfairia occidentalis samples from the study area during the dry season, as shown in (Table 1). In the wet season, the mean ± SD (0.03±0.01 mg kg-1) and % CV (51.63 %) were also recorded (Table 2). The overall average concentration of Ni in the leaves of fluted pumpkin from the study area was 0.03 mg kg-1 (Table 3), which is higher than that of the control sample but remains within the acceptable limits set by WHO for heavy metals in vegetables. The maximum concentration of 0.037 mg kg-1 was found at location 1 (Atabrikang), while the minimum concentration of 0.01 mg kg-1 was noted at location 7

(Iwo Opom) during the dry season, and Atabrikang during the wet season, respectively. Umudi et al., (2024) reported a mean concentration of 0.065 mg kg-1 for Nickel.

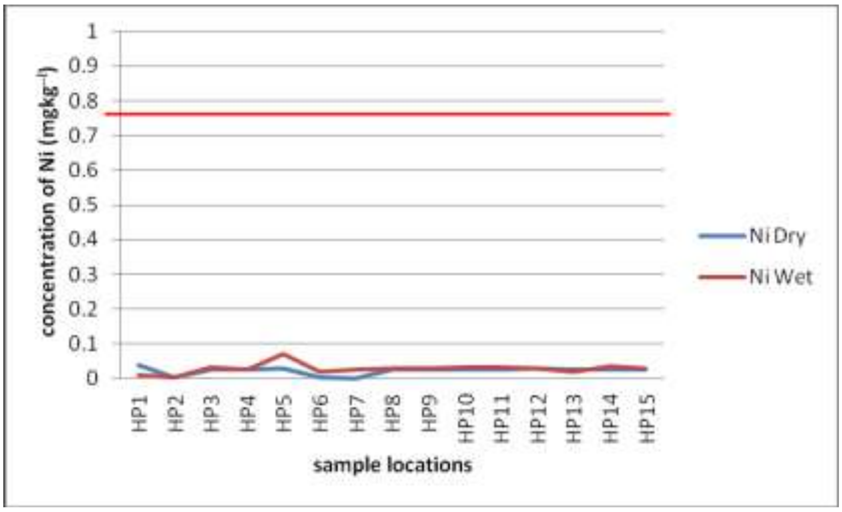

Figure 3: Seasonal Variations of Ni leaves of *Telfairia occidentalis* with WHO threshold

Vanadium (V)

The mean±SD concentration and %CV of vanadium (V) in Telfairia occidentalis were recorded as 0.16±0.25 mg kg-1 and 159.8 %, respectively, during the dry season, as shown in Table 1. Furthermore, the mean±SD concentration of V in the leaves of Telfairia occidentalis samples during the wet season was 0.206±0.295 mg kg-1, with a % CV of 143.072 %, as indicated in Table 2. The overall average concentration of V across both dry and wet seasons was determined to be 0.111 mg kg-1, as presented in Table 3. The concentration of vanadium found in the leaves of Telfairia occidentalis exceeded that of the control plant sample, with the highest concentration of 0.73 mg kg-1 observed at location 15 (Mkpanak) during the dry season (Table 1), while the lowest concentration of 0.01 mg kg-1 was recorded at location 8 (Okoritip) during the same season (Table 1). Umudi and Awatefe (2018) reported similar findings from the same state.

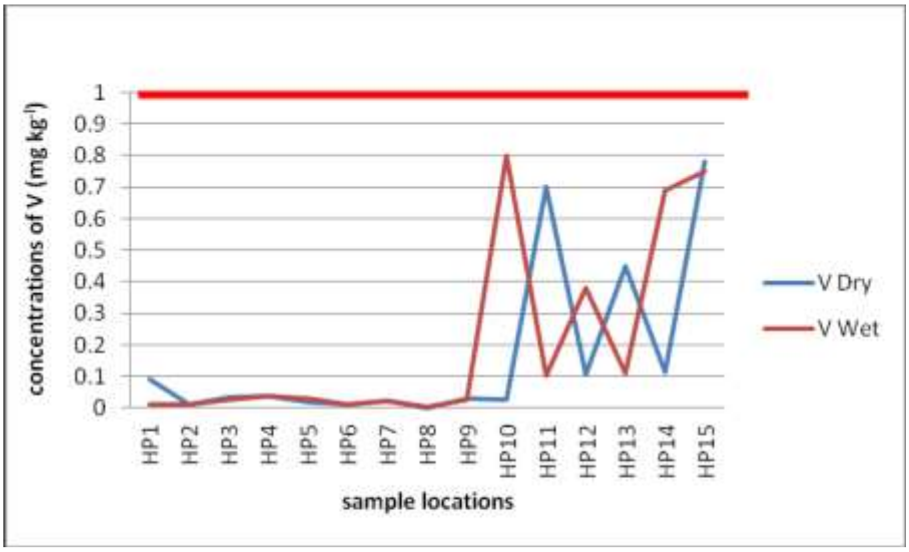

Figure 4: Seasonal Variations of V in leaves of *Telfairia occidentalis* with WHO standard

Cadmium (Cd)

The findings indicate that the average concentration of cadmium (Cd) in the leaves of Telfairia occidentalis during the dry season was 0.21 ± 0.20 mg kg-1, with a coefficient of variation (% CV) of 125.51%. These results are detailed in Table 1. In the wet season, the average concentration of Cd in the leaves of Telfairia occidentalis samples was found to be 0.17 ± 0.21 mg kg-1, as shown in Table 2. The overall average concentration of Cd in the leaves of Telfairia occidentalis was determined to be 0.202 mg kg-1 (Table 3). The mean concentrations for both the dry and wet seasons, along with the total average of Cd in Telfairia occidentalis, surpassed the guideline value of 0.1 mg kg-1 recommended by the World Health Organization (WHO), the Federal Ministry of Environment of Nigeria, and the German Federal Agency for Vegetables and Foodstuffs. Notably, cadmium was not detected in the control plant sample.

The highest concentration recorded was 0.613 mg kg-1 at location 15 (Mkpanak), while the lowest concentration of 0.004 mg kg-1 was observed at location 1 (Atabrikang). Additionally, cadmium was not detected in plant samples from locations 9, 10, and 11. In a related study conducted by Umudi (2019), the concentration of cadmium in the soils of the study area varied between 0.04 and 0.95 mg kg-1, compared to the naturally occurring cadmium concentration of 0.03 to 0.30 mg kg-1. Consequently, the cadmium concentration in the analyzed Telfairia occidentalis samples was significantly higher than the naturally occurring range. This suggests pollution, particularly given that cadmium is recognized as one of the most detrimental pollutants. A mean concentration of 0.28 ± 0.28 mg kg-1 of Cd in vegetables was also recorded.

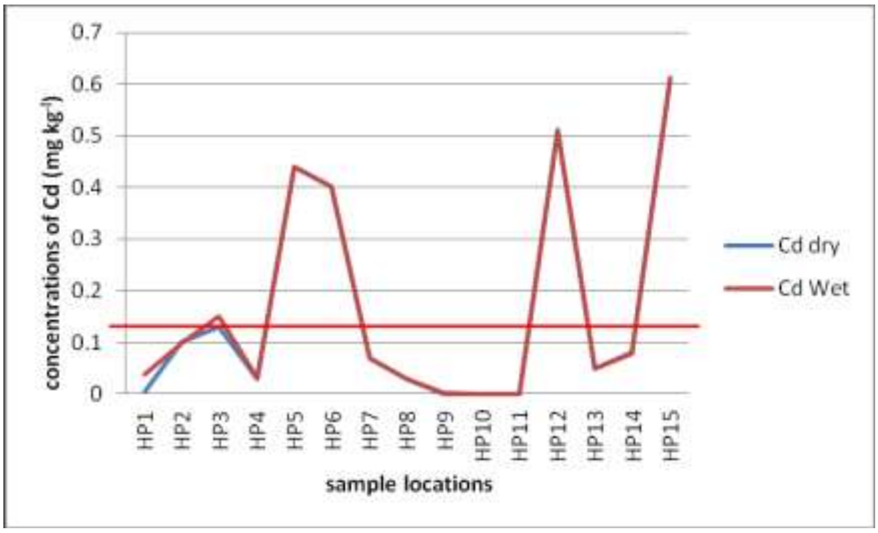

Figure 5: Seasonal variations of Cd in leaves of *Telfairia occidentalis*

Lead (Pb)

The average concentration and percentage coefficient of variation (% CV) of lead (Pb) in the leaves of Telfairia occidentalis within the study area were measured at 0.02±0.08 mg kg-1 and 108.546 %, respectively, during the dry season (refer to Table 1). In the wet season, the mean concentration was recorded at 0.09±0.05 mg kg-1, with a % CV of 58.066 % in the leaves of Telfairia occidentalis samples from the study area (see Table 2). The overall average concentration of 0.055 mg kg-1 was determined in the leaves of fluted pumpkin samples cultivated in the soil of the study area across both dry and wet seasons (refer to Table 3). The mean concentrations observed were marginally higher than the Pb levels found in the control plant sample. The mean concentration of 0.055 mg kg-1 falls within the World Health Organization (WHO) standard of 0.1 mg kg-1 for Pb in vegetables and the guideline value of

0.25 mg kg-1 for foodstuffs established by the German Federal Health Agency. In a comparable study conducted by Uboh et al. (2011), a mean concentration of 0.36 mg kg-1 Pb was reported, which is significantly higher than the 0.02 mg kg-1 found in this investigation. The majority of the risk associated with lead exposure is attributed to lead-contaminated soil or dust deposits on the plants, rather than the uptake of lead by the plants themselves. These findings are consistent with the research conducted by Obruche et al. (2018) in the Benue River, located in Makurdi.

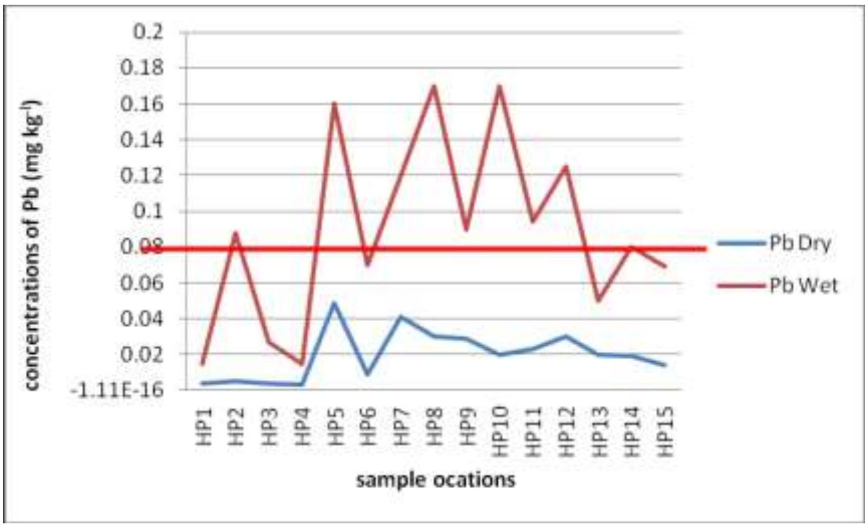

Figure 6: Seasonal Variations of Pb in leaves of *Telfairia occidentalis* with WHO threshold.

Manganese (Mn)

The findings indicate that the average concentration and % CV of Mn in the leaves of Telfairia occidentalis samples cultivated in the soil of the study area were 7.73 ± 0.93 mg kg-1 and 33.38 %, respectively, during the dry season (Table 1). In contrast, the average concentration of 7.75 ± 3.07 mg kg-1 and % CV of 39.599 % were recorded in fluted pumpkin samples grown in the same soil during the wet season (Table 2). The overall average concentration of Mn for both dry and wet seasons was determined to be 7.741 mg kg-1 (Table 3). These concentrations exceeded the Mn concentration of 4.00 mg kg-1 found in the control plant sample and the WHO standard of 6.0 mg kg-1 for Mn in vegetables. The highest concentration, measuring 12.987 mg kg-1, was observed at location 11 (Inua Eyet Ikot). These findings are consistent with the research conducted by Obruche et al. (2025) in the same Local Government Area.

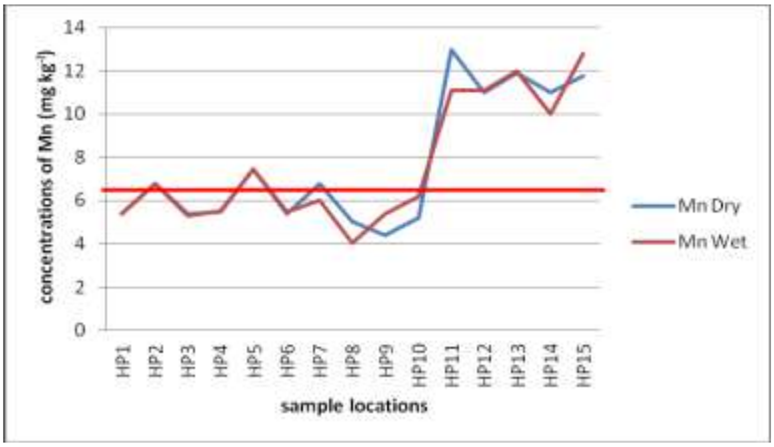

Figure 7: Seasonal Variations of Mn in leaves of *Telfairia occidentalis* with `WHO threshold

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Iron (Fe)

The mean concentration of iron (5.93±1.27 mg kg-1) and the coefficient of variation (% CV) at 21.575 % were observed in the leaves of Telfairia occidentalis samples cultivated in the study area (refer to Table 1). Furthermore, during the wet season, a mean concentration of 5.955±1.24 mg kg-1 and a % CV of 20.872 % were recorded (see Table 2). The overall average concentration of iron for both wet and dry seasons was determined to be 5.943 mg kg-1 (as shown in Table 3). The highest concentration, measuring 8.095 mg kg-1, was noted at location 2 (Ntafre), while the lowest concentration of 4.029 mg kg-1 was found at location 15 (Mkpanak) during the dry season (refer to Table 9). The mean concentration of iron in fluted pumpkin was significantly higher when compared to the concentration of the control plant sample (3.01 mg kg-1) and the World Health Organization standard (4.0 mg kg-1) for iron in vegetables. Idodo-Umeh Ogbeibu15 reported a mean concentration of 4.865 mg kg-1 of iron in cassava tubers from the study area. These findings are consistent with the research conducted by Onder et al. (2007) in the same state.

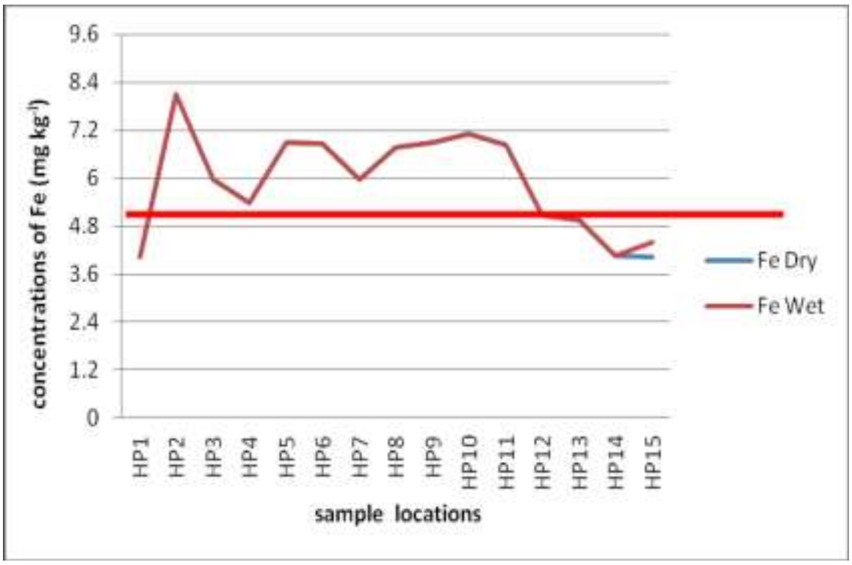

Figure 8: Seasonal Variations of Fe in leaves of *Telfairia occidentalis* with WHO standard

Zinc (Zn)

The average zinc level in the leaves of Telfairia occidentalis samples was found to be 0.03±0.027 mg kg-1, with a coefficient of variation (% CV) of 86.550 % recorded during the dry season (refer to Table 1). In contrast, the mean concentration during the wet season was 0.11±0.21 mg kg-1, with a % CV of 202.760 % for zinc (see Table 2). The overall average zinc concentration for both dry and wet seasons was 0.318 mg kg-1, as illustrated in Table 3.

The highest concentration, measuring 0.071 mg kg-1, was observed at location 14 (Okom Ita), while the lowest concentration of 0.001 mg kg-1 was noted at locations 1, 2, and 3 (Iwo Okpon). The total average concentration of 0.318 mg kg-1 of zinc in Telfairia occidentalis is relatively low when compared to the zinc concentration in control plant samples (0.01 mg kg-1) and the standards set by WHO. In a related study, Umudi et al (2024) reported a mean concentration of 4.89±0.5 mg kg-1 of zinc in tomato leaves, with a percentage covariant of 21.47 %, and a mean concentration of 3.33±0.52 mg kg-1 of zinc in tomato fruit within the study area.

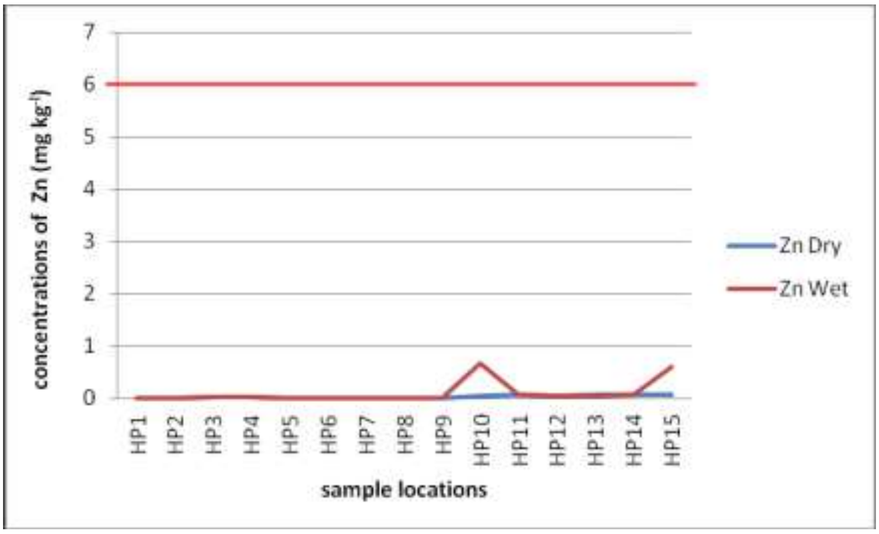

Figure 9: Seasonal Variations of Zn in leaves of *Telfairia occidentalis* with WHO standard

Cobalt (Co)

The average concentration of cobalt (Co) in the leaves of Telfairia occidentalis samples was measured at 0.10 ± 0.16 mg kg-1, with a coefficient of variation (% CV) of 99.06 % during the dry season in the study area (refer to Table 1). Additionally, during the wet season, the mean concentration was recorded at 0.0534 ± 0.023 mg kg-1, with a % CV of 43.44 % for Co in the leaves of Telfairia occidentalis samples (see Table 2). The total average concentration of Co across both dry and wet seasons was determined to be 0.077 mg kg-1 (as shown in Table 3). Itodo et al. (2021) reported a concentration of 1.23 mg kg-1 of Co in fluted pumpkin.

IV. CONCLUSION

At the time of this study, there were no existing reports regarding the levels of heavy metals in the leaves of Telfairia occidentalis and its properties as a bio-indicator in the region. Based on the findings of this research, it can be concluded that the mean concentrations of several heavy metals investigated (including nickel, vanadium, lead, zinc, and cobalt) in the leaves of Telfairia occidentalis fell within the acceptable range set by WHO standards for vegetables and food products, with the exception of cadmium, iron, and manganese. This study demonstrated that the leaves of Telfairia occidentalis (fluted pumpkin) serve as a valuable indigenous and environmentally friendly bio-indicator for anthropogenic influences of vanadium, lead, zinc, and manganese in the soil of the study area. In light of these results, the following recommendations are proposed: the cultivation of vegetables, such as Telfairia occidentalis, in the study area should be conducted only after a thorough assessment of heavy metal and other pollutant concentrations in the soil.

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