NIPES

Journal of Science and Technology Research

Journal homepage: www.nipesjournals.org.ng

Nickel and Vanadium in Edible Fruits and Vegetables, Potential Health Risk or Not?

Edene Osemudiamen, Ogbeide Grace and Ogbeide Ozekeke

Department of Environmental Management and Toxicology, University of Benin. Benin City, Nigeria.

Article Info

***Keywords*:**
Nickel, Vanadium, health risk, fruits, vegetables

Received 20 April 2023
Revised 30 April 2023
Accepted 30 April 2023
Available online 06 June 2023

https://doi.org/10.5281/zenodo.8010133

ISSN-2682-5821/© 2023 NIPES Pub.
All rights reserved.

Abstract

The presence of heavy metals in food has been linked to significant health risks. The increase in environmental pollution due to industrialization, urbanization, and agriculture has led to the frequent detection of toxic metals such as cadmium, lead, and mercury in foods. A study was conducted to determine the potential health hazards associated with consuming heavy metal-contaminated foods by measuring the quantities of heavy metals in various fruits and vegetables purchased from well-known markets in Benin City, Nigeria. The study analyzed fruit and vegetable samples, including oranges (Citrus sinesis), bananas (Musa acuminata), green leaf (Desmodium intortum), and pumpkin leaf (Telfairia occidentalis), obtained from three different markets. The samples were prepared according to standard procedures and analyzed using an inductively coupled plasma optical emission spectrometer (ICP-OES). The study also estimated human health risks using standard protocols. The results revealed different concentrations of heavy metals such as Manganese (Mn), Nickel (Ni), and Vanadium (V). Additionally, the study found that EDI and THQ values for bananas, green leaves, and pumpkin leaves exceeded the regulatory thresholds. As a result, this study highlights the importance of continuous monitoring and evaluation of heavy metals in fruits and vegetables because of their high consumption rate by the general public.

1.0. Introduction

Pollution and contamination of the human food chain have become unavoidable as a result of increasing human activity, particularly with the use of advanced technologies [1]. Fruits and vegetables are important food sources. They offer a varied, flavorful, colourful, appetizing, low-calorie, protective, and micronutrient-rich diet [2]. Consumption of fruits and vegetables, a crucial part of a healthy diet and lifestyle, has been established as a key factor in the prevention of many non-communicable diseases [2-4]. These advantages have made this class of food play a significant role in the human diet, hence heavy metal contamination in these foods cannot be understated [1, 2]. While there are several ways that food might get contaminated, the major danger to humans comes from heavy metal poisoning. Eating crops cultivated in soil and breathing the air near industrial zones are the main exposure sources of most metals [5, 6]. Even though fruits and vegetables include a variety of vitamins and minerals, as well as important fibre, which is beneficial for human health, they are also a rich source of contaminants including metals [7]. Health issues such as kidney and lung damage, cancer, low IQ, birth deformities, growth impairment, impacts on the central and peripheral nervous system, and reproductive and gonad toxicity have all been linked to exposure to metals through food and vegetable intake [7-10].

Approximately 80% of the vanadium produced worldwide is utilized as an additive in the steel industry. It is now an essential component of the iron-steel industry and other manufacturing facilities, including those that produce vehicles, ships, and fertilizers [5].

Vanadium, which is present in trace amounts, has industrial significance as a biological nutrient, epidemiological preventative, toxicant, environmental contaminant, and occupational health hazard. Although it is regarded as a necessary component for healthy cell development, greater concentrations of it have the potential to be harmful [5, 11].

Vanadium has more significance in marine environments than in terrestrial ones. It may be extremely toxic to both humans and animals and result in serious illnesses. [11, 12]. Therefore, there is a need to constantly monitor the levels of this metal in the environment. High vanadium concentrations might be harmful to humans, animals, plants, and microorganisms. High Vanadium concentrations, for instance, may result in poor root development and plant mortality [13, 14].

Vegetables inherently contain more nickel than animal meat does. It may be helpful as an enzyme system activator in very small doses, but its toxicity is more pronounced at greater concentrations [15]. In addition to environmental contamination sources, food processing operations including drying, heating, and canning in nickel-containing vessels can also contribute to the presence of nickel in food [15, 16]. It's been reported that High levels of nickel can also cause deficiencies in zinc or iron, as well as enzymatic dysfunction [17]. It has also been reported that at concentrations higher than the maximum permitted limits, nickel may be mutagenic [17, 18].

In general, fruits and vegetables are safe to eat, but if pollutants from them build up in people's bodies over time, they can cause significant health problems [19]. Furthermore, it has been reported that edible portions of vegetables are a convenient place for heavy metals to collect. This indicates that through absorption and accumulation, Heavy metals can be present in vegetables at levels deemed high enough to illicit harm to consumers [20, 21]. Several studies have reported the presence of heavy metals in fruits and vegetables all over the world including Volken [4], Taiwo and Awomeso [7], Taiwo [10], Onianwa [15], Amer [17], Bagdatlioglu [22], Colak [23], Elbagermi [24], Hamurcu [25], Hussain [26], Ihesinachi and Eresiya [27], Unaegbu [28]. This study aimed to measure the levels of Nickel and Vanadium in specific fruit and vegetable samples obtained from markets in Benin City, as well as evaluate the potential health risks posed by consuming these food items.

2. Materials and Methods

2.1 Study area

This study was carried out in Benin City (6.3350°N, 5.6037°E), the capital of Edo State, in the Tropical Rainforest zone of Southern Nigeria with an estimated land mass of 550 sq km [29]. The population of Benin City has been estimated to be approximately 1,676,000 in 2019. with a growth rate of 3.5% annually [30]. Three open markets within the city of Benin were selected for this study. They include Santana Market, Oba Market, and Uselu Market located in Ikpoba-Okha, Oredo, and Egor local governments area, in Benin City. The markets were selected after a reconnaissance study, which identified these markets as major fruits markets within Benin City.

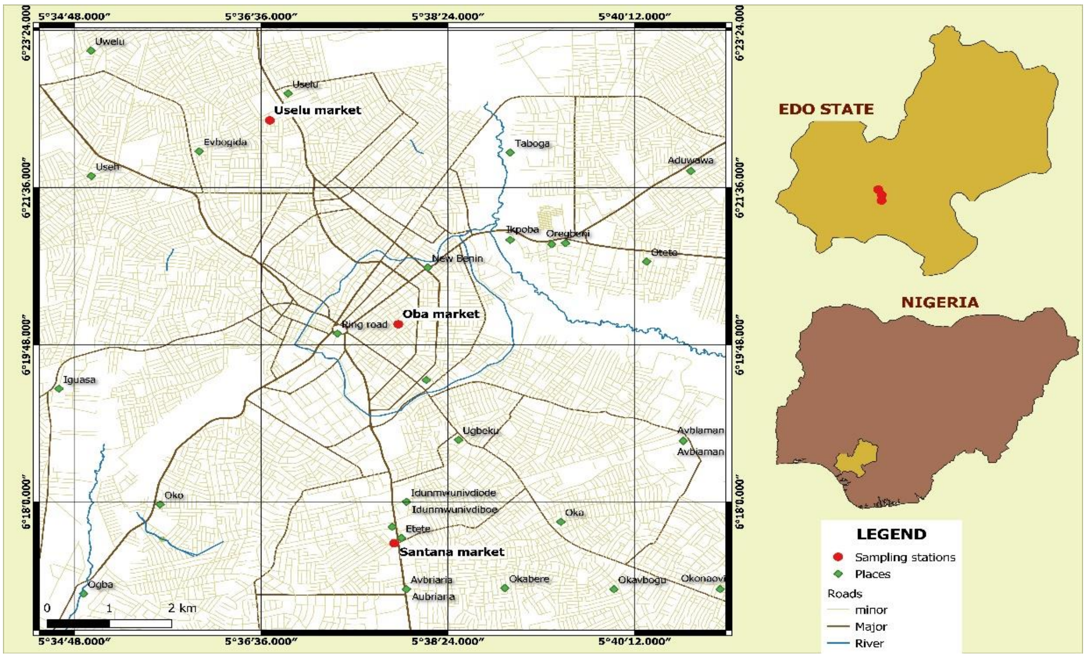

Figure 1: A map of the study area showing the various sampling locations

2.2 Sample Collection

A total of forty-eight (48) samples comprising fruits and vegetables (four oranges, four banana bunches, four bunches of green leaf and pumpkin leaf each) were collected from four different vendors in each market. The samples were collected in Ziplock bags, labelled appropriately and transported to the laboratory for further analysis.

Table 1 Names of vegetables and fruits analyzed

Name of Fruits /Vegetables	**Scientific Name**
Oranges	*Citrus sinesis*
Banana	*Musa acuminata*
Pumpkin leaf	*Telfairia occidentalis*
Green leaf	*Desmodium intortum*

2.3 Heavy Metal Extraction

To eliminate different airborne and soil pollutants, samples of fruits and vegetables were first washed in deionized water and then in distilled water based on the method described by [31]. The samples were then air-dried, pulverized, and kept in the lab at room temperature. Afterwards, 5g of the homogenized sample from each market was carefully weighed into crucibles and ashed at 450°C in a muffle furnace. The ash obtained was allowed to cool down and then digested using 1.0 ml of 36% HCl to obtain a transparent solution. A Whatman filter paper was used to rid the extracted substance of impurities before introduction into the ICP-OES.

2.4 Heavy Metal Analysis

The obtained extract was analyzed for heavy metals (Ni and Va) using Inductively Coupled Plasma-Mass Spectrometry (ICP-MS). The Operating optimal parameters used in the analysis were: RF generator **(1kw**), plasma gas flow (15L/min), auxiliary gas flow (1.5L/min), and the spray chamber type used was the glass cyclonic type. The torch used in the analysis was the standard axial torch. The nebulizer type was the sea spray and the gas pressure was 220kPa. The pump speed was 15rpm, sample uptake was 30s, replicate read time was 30s, the number of replicates was 2, sample delay time was 20s, stabilization time was 15s, rinse time was 10s and the fast pump was put on. After the instrument was programmed, the calibration curves were then obtained by running the standards and then the samples were also analyzed according to the sequence specified in the sequence parameters of the newly created worksheet.

2.5 Quality Assurance and Quality Control

Before analysis, the ICP-OES was given at least 30 minutes to stabilize to guarantee accuracy. Triplicate readings for each sample were collected, and a maximum error of 5% was detected.
The analysis run's validity of the calibration is verified continuously with the Continuous Calibration Verification Test, which is conducted at a 20% frequency (every 20 analytical samples). To confirm that the reagents and rinse solution were free of metal contamination, blanks were also tested.

2.6 Human Health Risk Assessment

Estimated average daily intakes (EADIs) of metals in food and assumption of food consumption were used to investigate long-term health risks to consumers [32]. To this end, EADI was estimated using the equation below;

$$EADI = \frac{C_{fruit} \times D_{foodintake}}{BW} \quad (1)$$

Where C_{metal} = Heavy metal concentration in plants (mg/kg)
$D_{food\ intake}$ = daily intake of vegetables (kg/person)
$B_{everage\ weight}$ = average body weight.
The average adult body weight is usually considered to be 70kg, while the average daily vegetable intake for adults is considered to be 0.345 kg/person/day, respectively [33, 34].

$$\text{Hazard quotient (HQ)} = \frac{EADI}{RfD} \quad (2)$$

$$\text{Hazard Index (HI)} = \Sigma HQ_n \quad (3)$$

The health risk index was calculated as the ratio of estimated exposure (EADI) of test vegetables/fruits and oral reference dose. This model has been described by USEPA (1992). Estimated exposure is obtained by dividing the daily intake of heavy metals by their safe limits. An index of more than 1 is considered as not safe for human health [35, 36]

2.7. Data Analyses

This study's findings are reported as mean and standard error. The homogeneity of variance and normality of the data attributes were assessed before parametric tests were run. To determine if there were any appreciable variations in Heavy Metal concentrations (spatial and temporal), a one-way analysis of variance was performed.

3.0. Results and Discussion

Analysis of fruits and vegetables obtained from selected markets in the Benin City metropolis showed varying concentrations of Nickel (Ni) and Vanadium (V). In *Musa acuminata* (Banana), it was observed that the highest concentration (0.73±0.15 mg/kg) of Ni was seen in Santana Market. The concentration of Ni in *M. acuminata* was significantly lower ($P \leq 0.05$) in Oba and Uselu Markets (Fig 2A). Santana Market also recorded the highest concentration (46.45±0.20 mg/kg) of Va in *Musa acuminata* compared to Oba and Uselu Markets (Fig 2B).

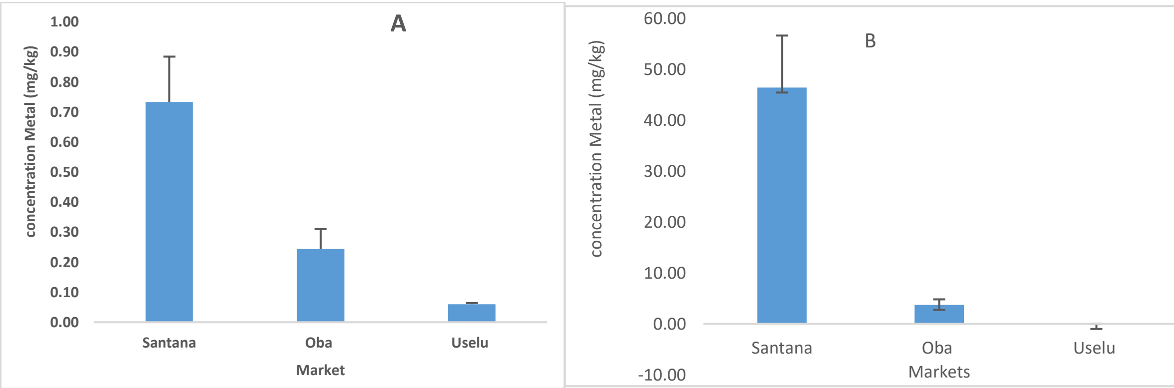

Figure 2: Mean concentration of Nickel (A) and Vanadium (B) in *Musa acuminata* (Banana) from selected markets in Benin City

The concentration of Ni in *D. intortum* (green leaf), was observed to be significantly higher (P≤0.05) in Santana Market (3.95±0.61mg/kg) compared to Oba and Uselu Markets (Fig 3A). On the other hand, the concentration of Va in *D. intortum* (green leaf), was highest in Oba Market although not significantly different (P≥0.05) from concentrations observed in *D. intortum* obtained from Santana Market (Fig 3B).

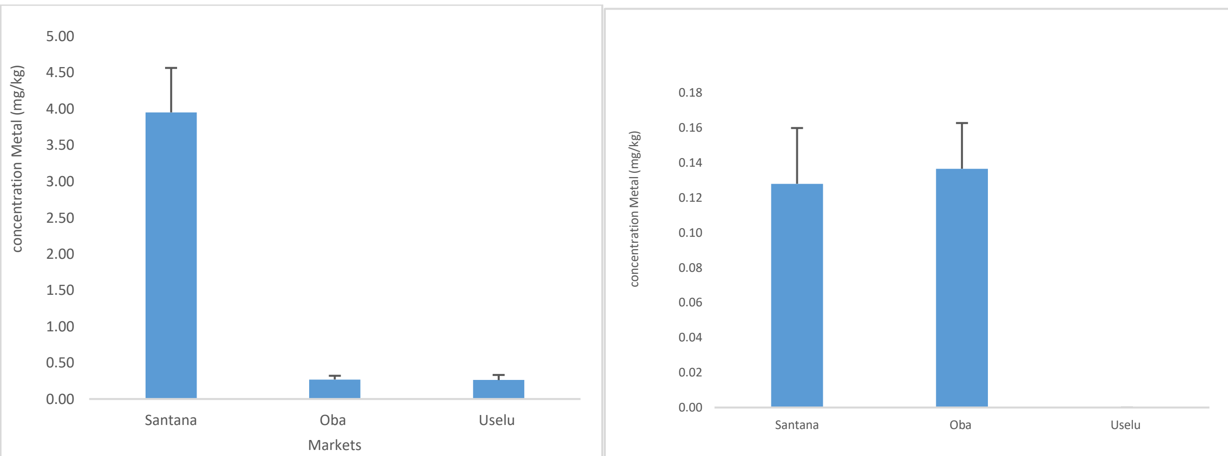

Figure 3: Mean concentration of Nickel (A) and Vanadium (B) in *D. intortum* (Green Leaf) from selected markets in Benin City

Nickel concentrations in *Telfairia occidentalis* (Pumpkin Leaf), were observed to be significantly (P≤0.05) higher (0.23± 0.06 mg/kg) in Oba Market, compared to the concentration in Santana (0.01±0.00 mg/kg) and Uselu (0.06± 0.0 mg/kg) respectively (Fig 4A). On the other hand, Va was only observed in Oba Markets (3.70±0.81 mg/kg) (Fig 4B).

3.1. Health risk assessment

Table 2 displays the estimated daily metal intake for each edible portion of a vegetable and fruits from selected markets within Benin City. Daily intake estimated for Ni in bananas from Santana Market showed values above the tolerable upper intake levels (UI) (0.0028 mg/kg) set by the European Union (EU) [37]. On the hand, DI estimated for Va in Banana from Oba Market (0.02 mg/kg/d) exceeded UI (0.20 mg/kg/d) set by USEPA [38]. EDI values for green leaf, where above the recommended UI values for Nickel in Santana Market, EDI values for Va in pumpkin leaf from Oba Market exceeded the UI value for Va in fruits and vegetables (Table 2).

Total target hazard quotient (TTHQ) where above 1 for metals in Banana and Green leaf from Santana Market, while TTHQ values for metals in Banana and Pumpkin leaf exceeded the threshold (1) (Table 2).

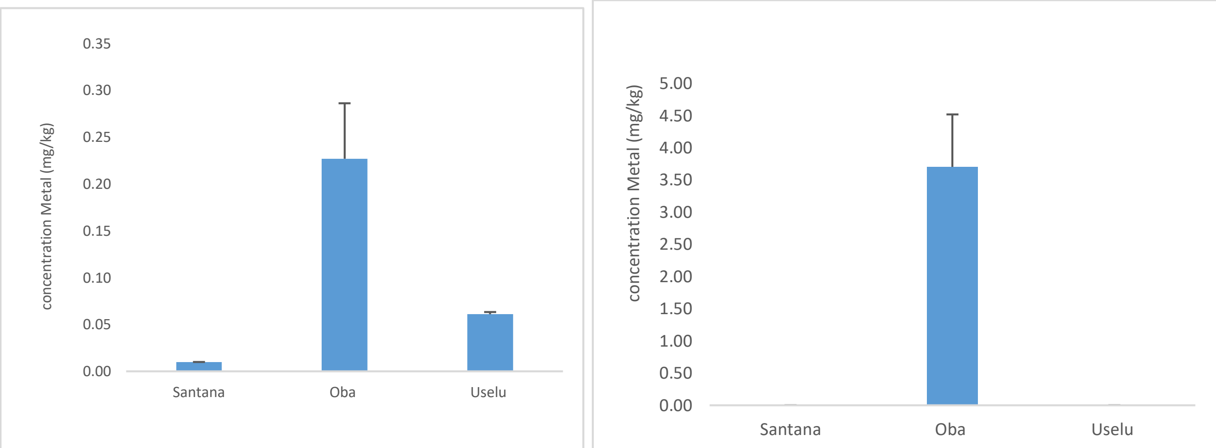

Figure 4: Mean concentration of Nickel (A) and Vanadium (B) in *Telfairia occidentalis (Pumpkin Leaf),* from selected markets in Benin City

The concentration of Ni in Oranges (*Citrus sinesis)* was highest in Oba Market (0.07±0.02 mg/kg) compared to Uselu (ND) and Santana Market (0.01 mg/kg) (Fig 5). It was observed that Van was below the detection limit in *Citrus sinesis* from all markets.

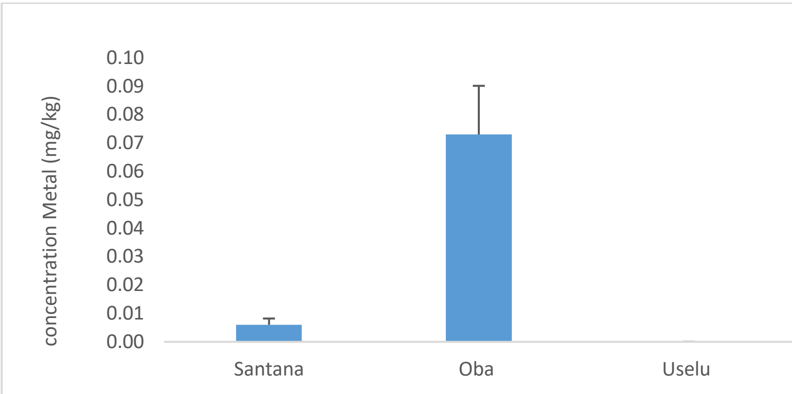

Figure 5: Mean concentration of Nickel in *Citrus sinesis (Oranges)*, from selected markets in Benin City

Table 2: Estimated Daily Intake and Target Hazard Quotient for metals in fruits and vegetables from selected markets in Edo State.

		BANANA		GREEN LEAF		PUMPKIN LEAF		ORANGE	
Markets	**Metals**	**EDI**	**THQ**	**EDI**	**THQ**	**EDI**	**THQ**	**EDI**	**THQ**
Santana	Nickel	0.0036**	0.18	0.02**	0.97	0.0000	0.00	0.0000	0.00
	Vanadium	0.2289***	25.44*	0.0006	0.07	0.0000	0.00	0.0000	0.00
	ΣTHQ		25.62*		1.04*		0.00		0.00
Oba	Nickel	0.0012	0.06	0.0013	0.07	0.0011	0.06	0.0003	0.02
	Vanadium	0.02***	2.05*	0.0007	0.08	0.02***	2.03*	0.0000	0.00
	ΣTHQ		2.11*		0.14		2.08*		0.02
Uselu	Nickel	0.0003	0.01	0.0013	0.06	0.0003	0.01	0.0000	0.00
	Vanadium	0.0000	0.00	0.0000	0.00	0.0000	0.00	0.0000	0.00
	ΣTHQ		0.01		0.06		0.01		0.00

* Above the recommended threshold of 1
** Above EU tolerable upper intake levels for Nickel
*** Above USEPA tolerable upper intake levels for vanadium

The best sources of nutritional fibre, nutrients, and some very essential vitamins are fruits and vegetables. [39-41]. They also contribute significantly to the total dietary antioxidant capacity (TDAC), an important food quality indicator, as they are an excellent source of beneficial antioxidant enzymes. [42, 43]. Despite these benefits, fruits and vegetables have been implicated as potential sources of heavy metals due to Heavy metals bioaccumulation, facilitated by wastewater irrigation, air deposition, and spillages [44]. Although fruits and vegetables are a major part of the Nigerian diet, they are very susceptible to environmental pollution due to the activities and processes going on or practised in the area where it is cultivated or obtained [45]. It's been reported that growing crops in contaminated soil causes trace metals to be absorbed, transported, and then bioaccumulated to dangerous amounts in edible plant tissues [46]. This scenario has led to an increased potential of heavy metals to bioaccumulate in the food chain causing serious health concerns [47]. Leafy fruits and vegetables like pumpkin leaves and green leaves are considered to have the ability to hyper-accumulate heavy metals [48].

In this study, varying concentrations of Ni and Va have been observed in fruit and vegetable samples from all markets selected. The presence of heavy metals in fruits and vegetables can be attributed to the absorption, and subsequent transfer of these metals from soil pores to plants in ionic forms [49]. Rainwater from polluted air-filled places and commercial fertilizers are two more sources of heavy metals in plants' edible portions [50].

The presence of Ni and Va in *Musa acuminata* (Banana) obtained from markets observed in this study agrees with findings by Okorie [50] who reported varying concentrations of heavy metals including Lead, Mercury and Arsenic in several varieties of *Musa acuminata* obtained from Umuahia main market, Abia State, Nigeria. Similarly, Maduforo [51] in a study in Enugu Nigeria, also reported concentrations of heavy metals(Arsenic, Lead and Mercury) in Banana samples obtained from various food vendors. Lashari [52] reports a concentration of Va in Banana samples obtained from contaminated fields in Tando Allayar, district Sindh of Pakistan. Concentrations of Ni were also reported in Banana samples produced and commercialized in Ecuador, which are among Ecuador's most exported products [53].

Citrus sinesis (oranges), had very low concentrations of Ni in the Santana and Oba market, while Va was not detected in samples from any of the study markets. Results obtained in this study are lower than those reported by Orisakwe Orish Ebere [21], Verma [54] and Amer [17], who reported concentrations of Ni in fruits in Nigeria, India and Egypt respectively.

In the same vein, samples of *Desmodium intortum* (green leaf) and *Telfairia occidentalis* (Pumpkin Leaf), obtained from the studied markets contained various concentrations of Ni and Va. The presence of heavy metals in vegetables could be attributed to the fact that leaves are the main part of the plant responsible for photosynthesis, thus higher metals are carried to the leaves by mass flow during strong transpiration [55]. Also, the wide leaf area of leaf vegetables makes them more prone to contaminant buildup from soil particles and precipitation [56]. The presence of heavy metals in leafy vegetables has also been reported in several studies in Nigeria including Ogunkunle [1], Doherty [57]; and Sobukola [58] who have all reported heavy metal concentrations in vegetables from various locations within Lagos State. Similarly, findings from this present study agree with Akan [59] who reported a concentration of HMs in vegetables obtained from Borno State, North Eastern Nigeria; Lawal and Audu [60] Lawal and Audu [60] and Edogbo [61] who reported varying concentrations of HMs in vegetables obtained from various locations in Kano Metropolis. Patrick-Iwuanyanwu and Nganwuchu [62] also reported a concentration of HMs in leafy vegetables obtained from selected markets in Bayelsa State.

3.2. Health risk assessment of heavy Nickel and Vanadium in Fruits and vegetables.

Amer [17] reports that there is considerable risk to consumers when the EDI (daily consumption of heavy metal residue) is more than the tolerable daily intake (TDI) which is the daily amount of heavy metal in food that can be used by humans for a long time with no health effects. Results of the health risk assessment presented in Table 2 showed Vanadium and Nickel concentrations in banana and green leaves from Santana Market and Oba Market exceeded the limits set by USEPA

[38] and EU [37]. This implies that daily consumption of contaminated banana samples from this market could pose a significant health risk to human consumers. Furthermore, THQ estimates in this study were above the threshold of 1 for bananas in Santana and Oba markets, green leaves in the Oba market and Pumpkin leaves in the Oba market. This indicates that the consumption of these fruits and vegetables from these markets could pose a non-carcinogenic risk to consumers. This finding agrees with reports by Amer [17], Edogbo [61], Patrick-Iwuanyanwu and Nganwuchu [62], Harmanescu [63], Sultana [64] who reported concentrations of various heavy metals in fruits and vegetables exceeding the tolerable daily intake.

4.0. Conclusion

The findings of the current study tend to indicate that the frequent consumption of fruits and vegetables from the markets under investigation in Benin City, Edo state, may be one of the factors contributing to the heavy metal burden among consumers, as well as an increased risk of non-carcinogenic diseases in the population

Conflict of Interest

The authors declare no conflict of interest

References

[1] Ogunkunle ATJ, Bello OS, Ojofeitimi OS. Determination of heavy metal contamination of street-vended fruits and vegetables in Lagos state, Nigeria. *International Food Research Journal*. 2014; **21**(6).
[2] Olatona FA, Sosanya A, Sholeye OO *et al.* Knowledge of fruits and vegetables, consumption pattern and associated factors among adults in Lagos State, Nigeria. *Research Journal of Health Sciences*. 2018; **6**(2): 50-62.
[3] Ogah OS, Madukwe OO, Onyeonoro UU *et al.* Cardiovascular risk factors and non-communicable diseases in Abia state, Nigeria: report of a community-based survey. *International Journal of Medicine and Biomedical Research*. 2013; **2**(1): 57-68.
[4] Volken T, Rüesch P, Guggisberg J. Fruit and vegetable consumption among migrants in Switzerland. *Public health nutrition*. 2013; **16**(1): 156-163.
[5] Imtiaz M, Rizwan MS, Xiong S *et al.* Vanadium, recent advancements and research prospects: a review. *Environment International*. 2015; **80**: 79-88.
[6] Lagerkvist BJS, Oskarsson A. Vanadium. 2007.
[7] Taiwo AM, Awomeso JA. Assessment of trace metal concentration and health risk of artisanal gold mining activities in Ijeshaland, Osun State Nigeria—Part 1. *Journal of Geochemical Exploration*. 2017; **177**: 1-10.
[8] Jarup L. Hazards of heavy metal contamination Br Med Bull 68: 167–182. *Find this article online*. 2003.
[9] Taiwo AM, Ige SO, Babalola OO. Assessments of possible gonadotoxic effect of lead on experimental male rabbits. *Global Veterinaria*. 2010; **5**(5): 282-286.
[10] Taiwo AM, Olowookere ZA, Bada BS *et al.* Contamination and health risk assessments of metals in selected fruits from Abeokuta, Southwestern Nigeria. *Journal of Food Composition and Analysis*. 2022; **114**: 104801. doi: https://doi.org/10.1016/j.jfca.2022.104801
[11] Abrarin S, Ahmed MJ. A highly sensitive and selective spectrophotometric method for the determination of vanadium at nanotrace levels in some environmental, biological, soil, food, and pharmaceutical samples using salicylaldehyde-benzoylhydrazone. *European Journal of Chemistry*. 2020; **11**(4): 385-395.
[12] Liao ZJ. Pollution, hazard, migrate and transform of micro amounts heavy metal elements in environment. Science Press, Beijing; 1989.
[13] Aihemaiti A, Gao Y, Meng Y *et al.* Review of plant-vanadium physiological interactions, bioaccumulation, and bioremediation of vanadium-contaminated sites. *Science of The Total Environment*. 2020; **712**: 135637.
[14] Olness A, Gesch R, Forcella F *et al.* Importance of vanadium and nutrient ionic ratios on the development of hydroponically grown cuphea. *Industrial Crops and Products*. 2005; **21**(2): 165-171.
[15] Onianwa PC, Lawal JA, Ogunkeye AA *et al.* Cadmium and nickel composition of Nigerian foods. *Journal of Food Composition and Analysis*. 2000; **13**(6): 961-969.
[16] Ankle M, Loesch E, Angelow L *et al.* Nickel exposure of food chain of plants, animals and man in Germany. 3. Nickel content of foodstuff! s and beverages of humans. *Mengen Spurenelem Arbeistag*. 1993; **13**: 400-414.
[17] Amer MM, Sabry BA, Marrez DA *et al.* Exposure assessment of heavy metal residues in some Egyptian fruits. *Toxicology Reports*. 2019; **6**: 538-543.

[18] Valko M, Morris H, Cronin MTD. Metals, toxicity and oxidative stress. *Current medicinal chemistry*. 2005; **12**(10): 1161-1208.
[19] D'Mello JPF. *Food safety: contaminants and toxins*. CABI, 2003.
[20] Alam MGM, Snow ET, Tanaka A. Arsenic and heavy metal contamination of vegetables grown in Samta village, Bangladesh. *Science of the total environment*. 2003; **308**(1-3): 83-96.
[21] Orisakwe Orish Ebere, Kanayochukwu Nduka John, Cecilia NA *et al.* Evaluation of potential dietary toxicity of heavy metals of vegetables. *J Environ Ana Toxi*. 2012; **2**(3): 136-139.
[22] Bagdatlioglu N, Nergiz C, Ergonul PG. Heavy metal levels in leafy vegetables and some selected fruits. *Journal für Verbraucherschutz und Lebensmittelsicherheit*. 2010; **5**: 421-428.
[23] Colak H, Soylak M, Turkoglu O. Determination of trace metal content of various herbal and fruit teas produced and marketed in Turkey. *Trace Elements & Electrolytes*. 2005; **22**(3).
[24] Elbagermi MA, Edwards HGM, Alajtal AI. Monitoring of heavy metal content in fruits and vegetables collected from production and market sites in the Misurata area of Libya. *International Scholarly Research Notices*. 2012; **2012**.
[25] Hamurcu M, Özcan MM, Dursun N *et al.* Mineral and heavy metal levels of some fruits grown at the roadsides. *Food and Chemical toxicology*. 2010; **48**(6): 1767-1770.
[26] Hussain S, Rengel Z, Qaswar M *et al.* Arsenic and heavy metal (cadmium, lead, mercury and nickel) contamination in plant-based foods. *Plant and Human Health, Volume 2: Phytochemistry and Molecular Aspects*. 2019: 447-490.
[27] Ihesinachi K, Eresiya D. Evaluation of heavy metals in orange, pineapple, avocado pear and pawpaw from a farm in Kaani, Bori, Rivers State Nigeria. *Journal Issues ISSN*. 2014; **2360**: 8803.
[28] Unaegbu M, Engwa GA, Abaa QD *et al.* Heavy metal, nutrient and antioxidant status of selected fruit samples sold in Enugu, Nigeria. *International Journal of Food Contamination*. 2016; **3**: 1-8.
[29] Osawaru ME, Ogwu MC. Plants and plant products in local markets within Benin City and environs. In: *African handbook of climate change adaptation*. Springer; 2021. 315-337.
[30] Fabolude G, Aighewi IT. Evaluation of the Extent of Land Use-Land Cover Changes of Benin City, Edo State, Nigeria from 1987-2019. *Journal of Applied Sciences and Environmental Management*. 2022; **26**(8): 1443-1450.
[31] Mawari G, Kumar N, Sarkar S *et al.* Heavy metal accumulation in fruits and vegetables and human health risk assessment: findings from Maharashtra, India. *Environmental Health Insights*. 2022; **16**: 11786302221119151.
[32] Fathabad AE, Shariatifar N, Moazzen M *et al.* Determination of heavy metal content of processed fruit products from Tehran's market using ICP-OES: a risk assessment study. *Food and chemical toxicology*. 2018; **115**: 436-446.
[33] Wang X, Sato T, Xing B *et al.* Health risks of heavy metals to the general public in Tianjin, China via consumption of vegetables and fish. *Science of the total environment*. 2005; **350**(1-3): 28-37.
[34] Orisakwe OE, Nduka JK, Amadi CN *et al.* Heavy metals health risk assessment for population via consumption of food crops and fruits in Owerri, South Eastern, Nigeria. *Chemistry central journal*. 2012; **6**(1): 1-7.
[35] USEPA USEPA. Definitions and general principles for exposure assessment. Guidelines for exposure assessment. Office of Pesticide Programs Washington, DC, USA; 1992.
[36] USEPA USEPA. *Risk Assessment Guidance for Superfund: pt. A. Human health evaluation manual*. Office of Emergency and Remedial Response, US Environmental Protection Agency, 1989.
[37] EFSA EFSA. Scientific Opinion on the risks to public health related to the presence of nickel in food and drinking water. *EFSA Journal*. 2015; **13**(2): 4002.
[38] USEPA USEPA. *Health Effects Assessment for Vanadium and Compounds.* . Cincinnati, Ohio: Office of Research and Development,Environmental Criteria and Assessment Office, ; 1987 (DHHS publication no.: Report Number)| (GPO. Document Number)|.
[39] Kader A. Importance of fruits, nuts, and vegetables in human nutrition and health. *Perishables handling quarterly*. 2001; **106**(4): 6.
[40] Quebedeaux B, Bliss FA. Horticulture and human health: contributions of fruits and vegetables: proceedings of the 1st International Symposium on Horticulture and Human Health, Arlington, Va., 12-15 April, 1987. In: Prentice Hall in cooperation with American Society for Horticultural Science ….
[41] Wargovich MJ. Anticancer properties of fruits and vegetables. *HortScience*. 2000; **35**(4): 573-574.
[42] Hervert-Hernández D, García OP, Rosado JL *et al.* The contribution of fruits and vegetables to dietary intake of polyphenols and antioxidant capacity in a Mexican rural diet: Importance of fruit and vegetable variety. *Food Research International*. 2011; **44**(5): 1182-1189.
[43] Saura-Calixto F, Goni I. Definition of the Mediterranean diet based on bioactive compounds. *Critical reviews in food science and nutrition*. 2009; **49**(2): 145-152.
[44] Oluwole SO, Olubunmi MSC, Kafeelah AY *et al.* Determination of heavy metal contaminants in leafy vegetables cultivated by the road side. *Int J Eng Res Dev*. 2013; **7**(3): 1-5.

[45] Adedokun AH, Njoku KL, Akinola MO *et al.* Potential human health risk assessment of heavy metals intake via consumption of some leafy vegetables obtained from four market in Lagos Metropolis, Nigeria. *Journal of Applied Sciences and Environmental Management*. 2016; **20**(3): 530-539.
[46] Onyedikachi UB, Belonwu DC, Wegwu MO. Human health risk assessment of heavy metals in soils and commonly consumed food crops from quarry sites located at Isiagwu, Ebonyi State. *Ovidius University Annals of Chemistry*. 2018; **29**(1): 8-24.
[47] Khan A, Khan S, Khan MA *et al.* The uptake and bioaccumulation of heavy metals by food plants, their effects on plants nutrients, and associated health risk: a review. *Environmental science and pollution research*. 2015; **22**: 13772-13799.
[48] Khanna P. Assessment of heavy metal contamination in different vegetables grown in and around urban areas. *Research journal of environmental toxicology*. 2011; **5**(3): 162.
[49] Rai PK, Lee SS, Zhang M *et al.* Heavy metals in food crops: Health risks, fate, mechanisms, and management. *Environment international*. 2019; **125**: 365-385.
[50] Okorie DO, Eleazu CO, Nwosu P. Nutrient and heavy metal composition of plantain (Musa paradisiaca) and banana (Musa paradisiaca) peels. *Journal of Nutrition & Food Sciences*. 2015; **5**(3): 1-3.
[51] Maduforo AN, Okoro CE, Ogbuabo DA *et al.* Heavy metal in banana (Musa acuminata) varieties sold by fruit vendors in Enugu state, Nigeria. *Journal of Dietitians Association of Nigeria*. 2020; **11**(2): 52-57.
[52] Lashari A, Kazi TG, Afridi HI *et al.* Impact of oil well drilling activities on vanadium in soil, ground water, vegetables, fruits, and feed crops: a risk assessment. *International Journal of Environmental Science and Technology*. 2023: 1-10.
[53] Romero-Estévez D, Yánez-Jácome GS, Simbaña-Farinango K *et al.* Distribution, contents, and health risk assessment of cadmium, lead, and nickel in bananas produced in Ecuador. *Foods*. 2019; **8**(8): 330.
[54] Verma A, Sharma P, Dhusia N *et al.* Determination of heavy metal content in fruits and fruits juices consume in urban areas of Lucknow, India. *International Journal of Food Science and Nutrition*. 2016; **1**(5): 44-50.
[55] Stalikas CD, Chaidou CI, Pilidis GA. Enrichment of PAHs and heavy metals in soils in the vicinity of the lignite-fired power plants of West Macedonia (Greece). *Science of the Total Environment*. 1997; **204**(2): 135-146.
[56] Chang C-Y, Yu HY, Chen JJ *et al.* Accumulation of heavy metals in leaf vegetables from agricultural soils and associated potential health risks in the Pearl River Delta, South China. *Environmental monitoring and assessment*. 2014; **186**: 1547-1560.
[57] Doherty VF, Sogbanmu TO, Kanife UC *et al.* Heavy metals in vegetables collected from selected farm and market sites in Lagos, Nigeria. *Global Adv Res J Environ Sci Toxicol*. 2012; **1**(6): 137-142.
[58] Sobukola OP, Adeniran OM, Odedairo AA *et al.* Heavy metal levels of some fruits and leafy vegetables from selected markets in Lagos, Nigeria. *African Journal of food science*. 2010; **4**(2): 389-393.
[59] Akan JC, Kolo BG, Yikala BS *et al.* Determination of some heavy metals in vegetable samples from Biu local government area, Borno State, North Eastern Nigeria. *International Journal of Environmental Monitoring and Analysis*. 2013; **1**(2): 40-46.
[60] Lawal AO, Audu AA. Analysis of heavy metals found in vegetables from some cultivated irrigated gardens in the Kano metropolis, Nigeria. *Journal of Environmental chemistry and Ecotoxicology*. 2011; **3**(6): 142-148.
[61] Edogbo B, Okolocha E, Maikai B *et al.* Risk analysis of heavy metal contamination in soil, vegetables and fish around Challawa area in Kano State, Nigeria. *Scientific African*. 2020; **7**: e00281.
[62] Patrick-Iwuanyanwu K, Nganwuchu C. Evaluation of heavy metals content and human health risk assessment via consumption of vegetables from selected markets in Bayelsa State, Nigeria. *Biochem Anal Biochem*. 2017; **6**(332): 2161-1009.
[63] Harmanescu M, Alda LM, Bordean DM *et al.* Heavy metals health risk assessment for population via consumption of vegetables grown in old mining area; a case study: Banat County, Romania. *Chemistry Central Journal*. 2011; **5**: 1-10.
[64] Sultana M, Mondol MN, Mahir AA *et al.* Heavy metal concentration and health risk assessment in commonly sold vegetables in Dhaka city market. *Bangladesh Journal of Scientific and Industrial Research*. 2019; **54**(4): 357-366.