

Level of Heavy Metals in Commonly Consumed Leafy Vegetables Sold in Major Markets within Ibadan Metropolis, South Western, Nigeria

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Received September 02, 2024; Revised October 03, 2024; Accepted October 09, 2024

Abstract **Background** Heavy metal contamination of vegetables compromises the quality and safety of vegetables consumed in Nigeria. Information on the level of heavy metal in commonly consumed vegetables is critical to promoting food safety, hence this study was carried out to determine the level of heavy metals in commonly consumed vegetables on sales in selected markets in Ibadan metropolis, Nigeria. **Methodology** The study design was laboratory based experimental study where five (5) different leafy vegetables namely; *Celosia argentea* (soko), *Corchorus olitorius* (ewedu), *Amaranthus viridis* (tete), *Talinum triangulare* (water leaf) and *Telfaria occidentalis* (ugwu) commonly consumed were collected at different intervals in the various markets for a period of 12 weeks. Heavy metal concentration: (Lead (Pb), Cadmium (Cd), Zinc (Zn), Nickel (Ni) and Copper (Cu) were measured using Atomic Absorption Spectrophotometer. Data were analysed using descriptive statistics, one way ANOVA and comparison were made through t-test and line graphs. **Results** The results showed that lead (Pb) concentration in water leaf (1.70 ± 2.07 mg/kg), also in Ugwu (0.43 ± 0.35 mg/kg) and copper concentration in water leaf (0.22 ± 0.14 mg/kg) exceeded the WHO/FAO standard. However, there are higher concentration of cadmium, zinc, and nickel in some vegetables whereas others are within the safe limit. Mean heavy metal concentration was significantly higher in the evening samples than morning samples for all the heavy metals tested. ($P < 0.05$). However, Mean Nickel (Ni) concentration was lower across all the vegetables assessed when compared with the standards. **Conclusion** Vegetables sold in the studied markets were laden with heavy metals of public health importance. Consistent monitoring and assessment of heavy metal contamination of vegetables sold in markets by regulatory authorities are recommended in the interest of the public and to promote food safety.

Keywords: Heavy metals, vegetables, Market, Food safety

Cite This Article: Dada A. O, Mekanjuola B. C, and Adewumi M. O, "Level of Heavy Metals in Commonly Consumed Leafy Vegetables Sold in Major Markets within Ibadan Metropolis, South Western, Nigeria." *Journal of Environment Pollution and Human Health*, vol. 12, no. 2 (2024): 24-30. doi: 10.12691/jephh-12-2-2.

1. Introduction

Food safety is of noteworthy concern around the world. During the most recent decades, the expanding interest for food security has invigorated research as regards to the hazard related with utilization of foodstuffs tainted by pesticides, heavy metals as well as other pollutants [1]. Vegetables establish basic parts of the diet routine, by contributing protein, nutrients, iron, calcium and other components, which are difficult to come by [2]. In spite of these points of interest, these plants might be polluted with heavy metals (for example lead, chromium, cadmium and copper) through natural approach or other human activities for examples the introduction of manures or metal-based pesticides, transportation, the collecting procedure, stockpiling and additionally at the purpose of offer. Numerous anthropogenic sources, for example,

waste burning, industrial and above all, vehicular traffic discharges heavy metals into the environment. Along these lines, the take-up and bioaccumulation of heavy metals in vegetables are affected by numerous variables, for example, atmosphere, climate affidavits, the convergences of heavy metals in soil, the nature of soil and the level of development of the plants at gather [3].

The contamination of vegetables with heavy metals because of soil and climatic contamination represents a risk to its quality and wellbeing. Dietary admission of heavy metals likewise stances hazard to creatures and human wellbeing. High centralizations of heavy metals (Cu, Cd and Pb) in products of the soil were identified with high predominance of upper gastrointestinal malignant growth [4]. Numerous anthropogenic sources, for example, squander burning, mechanical procedures and above all, vehicular traffic produces heavy metals into the climate.

The take-up and bioaccumulation of heavy metals in

vegetables are impacted by numerous components, for example, atmosphere, climate testimonies, the centralizations of heavy metals in soil, the nature of soil and the level of development of the plants at collect (Tóth et al., 2016). Air contamination may represent a danger to post-gather vegetables during transportation and promoting causing raised dimensions of heavy metals in vegetables [5]. Raised dimensions of heavy metals in vegetables are accounted for which, for example, long haul employments of treated or untreated wastewater [6]. Other anthropogenic sourcess of heavy metals incorporate the expansion of excrements, sewage slop, manures and pesticides which may influence the update of heavy metals by adjusting the physico-synthetic properties of the dirt, for example, pH, natural issue, bioavailability of heavy metals in the dirt [7]. The dimensions of heavy metals (Zn, Mn, Cu and Pb) in vegetable (*Talinum triangulare*) gathered from dumpsites of Lagos, Nigeria were observed to be high because of vehicular traffic outflow [8]. Fischer and Fischer-García (2023) reported high concentration of heavy metals in unwashed verdant vegetables than washed vegetables sold in street side of Colombia. The purpose of this study is to assess the heavy metal level in commonly consumed vegetables sold in Ibadan markets, Nigeria. It is expected that the findings of this study would inform the pollution status and public health risk of consumption of these leafy plants. The outcome of the study would suggest the type of appropriate interventions that could reduce heavy metal level in vegetables meant for public consumption.

2. Methods

2.1. Study Area

Three (3) major market sites in Ibadan metropolis, Oyo State, Nigeria were considered with different geographical characteristics viz a viz Bodija market within a periphery of an area characterized by good roads, availability of pipe borne water, good housing with sanitary facilities; Oje market belonging to the traditional inner core area of Ibadan typified by poor road network, poor housing, and lack of pipe borne water and Gate market which symbolized by high traffic density.

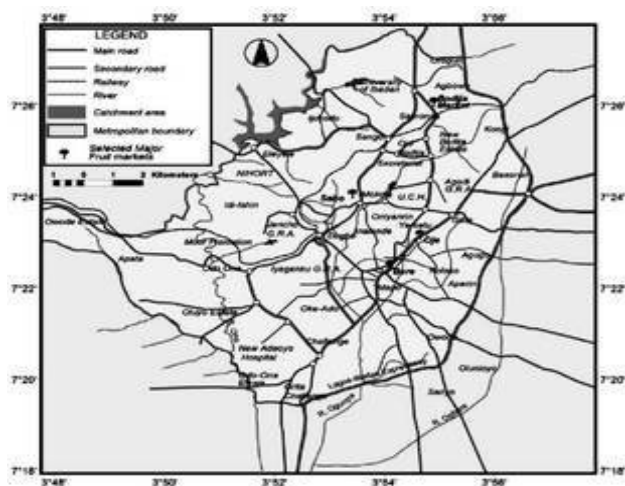


Plate 1. Map of Ibadan showing major Markets



Plate 2. Oje market at a glance

2.2. Collection of the Vegetables

five (5) most commonly consumed leafy vegetables namely; Soko (*Celosia argentea*), Ewedu (*Corchorusolitorius*), Green/Tete (*Amaranthusviridis*), Water leaf (*Talinumtriangulare*) and Ugwu (*Cucurbita maxima*) were purchased and collected twice daily: morning (8 - 9a.m) and evening (4 – 5p.m) from randomly selected five (5) vendors, the vegetables were properly preserved and taken immediately to the laboratory.

2.3. Preparation of the Vegetables for Analysis

The vegetable samples collected were washed thoroughly with distilled water to remove adsorbed elements. The samples were cut into small pieces and then dried using the oven dry method at 105°C for 24 hr (Memmert UF 260 plus 230V Sunon model) to remove the moisture content. The dry samples were ground to powder and then passed through a 1 mm sift. 0.5 g of sample was taken in reference vessels, 6 ml of 65% HNO₃, 3 ml of 70% HClO₄ and 1 ml of 30% H₂O₂ were added and carousel was positioned into microwave unit [18]. The mixture was heated at 80°C over 3 hr on block digester (microwave digester). After digestion was completed, the clear and colorless solution was filtered using Whatman filter paper No.42 and diluted with deionized water to raise the volume of the solution up to 50 mL (United State Environmental Protection Agency (USEPA) method: 3052A, 2016) and finally stored in plastic bottles which was followed by analysis for the heavy metal concentration; Lead (Pb), Cadmium (Cd), Zinc (Zn), Nickel (Ni) and Copper (Cu) using Atomic Adsorption Spectrophotometer (SP-IAA4530 Model, USA). Atomic absorption spectrometry (AAS) is a quantitative method of metal analysis suitable for the determination of approximately 70 elements. This method measures the concentration of the element by passing light of a specific wave length emitted by a radiation source of a particular element through clouds of atoms from a sample. Atoms will absorb light from an energy source known as hollow cathode lamp (HCL). The reduction in the amount of light intensity reaching the detector is seen as a measure for the concentration of a particular element in the original sample.

3. Results

3.1. Concentrations of Heavy Metals by Locations

Lead Concentration in Vegetables by Location

Figure 1 depicts the different level of Pb concentration in the vegetables in the different markets at different times of the day in comparison to the WHO/FAO standard of 0.3mg/kg. Pb concentration is below the standard in Bodija, it is however above the standard in Gate and Oje with morning samples having a higher Pb concentration than the evening samples at the three locations.

Cadmium concentration in vegetables by location

Cadmium concentration in vegetable samples was

higher in the evening samples than the morning samples. It was also higher in morning samples from Gate and the evening samples from Oje.

Zinc concentration in vegetables by location

The different in zinc concentration in the vegetable samples from all markets were almost the same and fell below the WHO/FAO standard.

Nickel concentration in vegetables by location

Nickel concentration in the vegetable samples varied in the different markets with evening samples in Bodija and Gate been above the recommended levels.

Copper concentration in vegetables by location

Copper concentration was higher in the evening samples and was highest in samples from Oje market and lowest in samples from Bodija market.

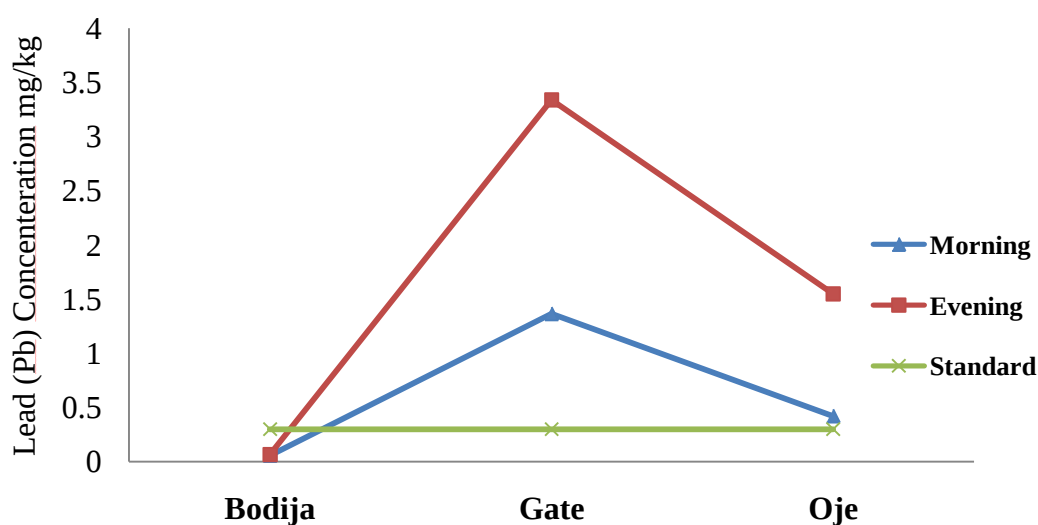


Figure 1. Pb Concentration

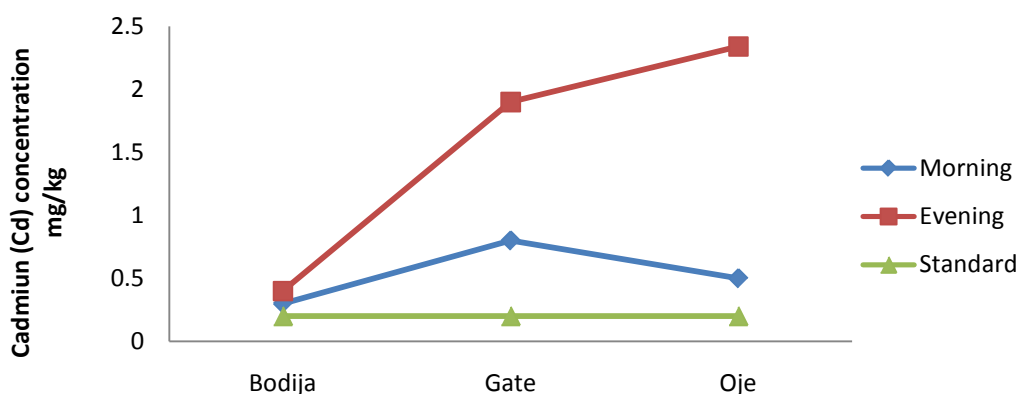


Figure 2. Cd Concentration

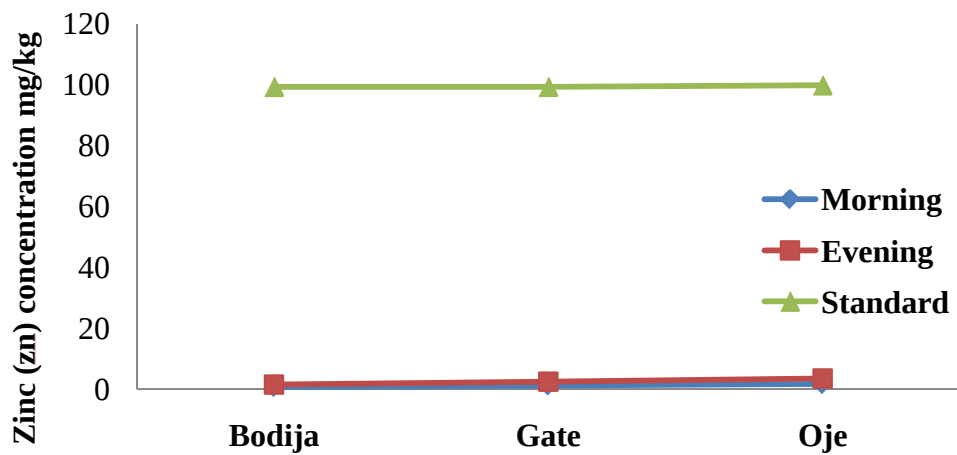


Figure 3. Zn Concentration

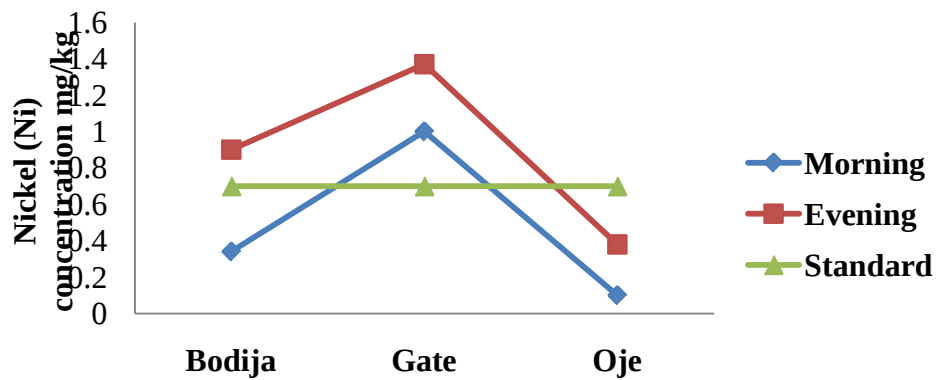


Figure 4. Ni Concentration

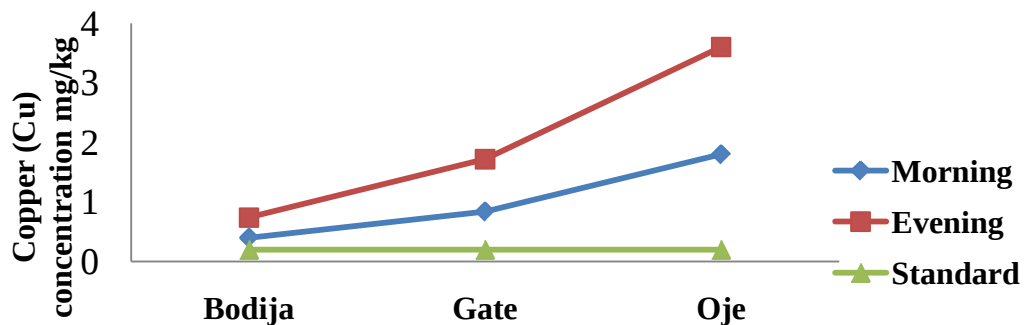


Figure 5. Cu Concentration

3.2. Comparison of Mean Heavy Metal Concentration with the Joint FAO/WHO Standard [17]

Comparison of mean heavy metal concentration with WHO/FAO standard (0.3mg/kg) as shown in Table 1 indicated that the mean lead concentrations were significantly higher than the approved standard in all the

vegetable samples. However mean lead concentration in ugwu (morning sample) was significantly lower (0.02 ± 0.01 mg/kg) than the approved standard ($p < 0.001$). Meanwhile, cadmium concentration in the vegetables when compared with the WHO/FAO standard (0.2mg/kg) showed that there was no significant difference in the mean cadmium concentration in all samples of soko and tete, cadmium concentration in ugwu and water leaf

(evening samples) were above the WHO/FAO approved standard (0.26mg/kg and 0.22mg/kg) respectively. This was however not statistically significant.

Zinc concentration in Soko, Ewedu and Tete vegetables were significantly higher than the WHO/FAO standard ($P < 0.05$). However, mean nickel concentration in all the vegetable was significantly below the WHO/FAO

standard in all vegetable samples assessed ($P < 0.05$). Copper concentration in the morning samples of soko (0.08mg/kg) and ewedu (0.04mg/kg) were significantly below the standard. Copper concentration in afternoon waterleaf samples were above the standard, though not statistically significant.

Table 1. Mean Heavy Metal Concentrations in all the vegetables

	HEAVY	Pb	Cd	Zn	Ni	Cu
	METALS					
SAMPLE	MEAN±SD mg/kg	MEAN±SD mg/kg	MEAN±SD mg/kg	MEAN±SD mg/kg	MEAN±SD mg/kg	MEAN±SD mg/kg
SOKO						
Morning	0.49±0.43	0.01±0.01	0.17±0.12	0.04±0.52	0.08±0.04	
Afternoon	1.39±1.20	0.04±0.01	0.40±0.10	0.11±0.16	0.15±0.13	
Average	0.94±0.81	0.02±0.01	0.29±0.10	0.08±0.11	0.11±0.08	
EWEDU						
Morning	0.68±1.14	0.03±0.02	0.22±0.18	0.11±0.16	0.04±0.05	
Afternoon	1.48±1.72	0.22±0.14	0.33±0.37	0.15±0.21	0.09±0.09	
Average	1.08±1.41	0.12±0.06	0.28±0.27	0.13±0.19	0.07±0.07	
UGWU						
Morning	0.02±0.01	0.07±0.12	0.05±0.05	0.01±0.01	0.10±0.10	
Afternoon	0.84±0.70	0.26±0.38	0.21±0.16	0.04±0.01	0.20±0.24	
Average	0.43±0.35	0.17±0.25	0.13±0.97	0.03±0.01	0.17±0.17	
WATERLEAF						
Morning	1.09±1.78	0.13±0.19	0.03±0.02	0.02±0.01	0.15±0.09	
Afternoon	2.31±2.44	0.22±0.31	0.05±0.01	0.04±0.02	0.29±0.19	
Average	1.71±2.07	0.17±0.25	0.04±0.02	0.03±0.01	0.22±0.14	
TETE						
Morning	0.79±0.52	0.02±0.01	0.13±0.14	0.08±0.11	0.14±0.14	
Afternoon	2.22±2.67	0.05±0.01	0.25±0.23	0.09±0.09	0.24±0.20	
Average	1.50±1.50	0.03±0.002	0.19±0.18	0.09±0.19	0.19±0.17	

FAO/WHO Standard: (lead = 0.3mg/kg), (cadmium = 0.2 mg/kg), (zinc = 0.12mg/kg), (nickel = 0.7mg/kg), (copper = 0.2mg/kg) [17]

Table 2. Comparing the total mean heavy metal concentrations in vegetables by time of the day

HEAVY METAL	MEAN CONC.	SD	MEAN DIFFERENCE (SD)	T	P-VALUE
LEAD					
Morning	0.62	0.22			
Afternoon	1.65	1.70	-1.04 (1.12)	-3.585	0.003
CADBIUM					
Morning	0.51	0.16			
Afternoon	0.16	0.12	-0.10(0.15)	-2.756	0.015
ZINC					
Morning	0.12	0.02			
Afternoon	0.25	0.22	-0.13(0.12)	-4.109	0.001
NICKEL					
Morning	0.51	0.06			
Afternoon	0.09	0.02	-0.37(0.05)	-2.803	0.014
COPPER					
Morning	0.10	0.01			
Afternoon	0.20	0.11	-0.10(0.10)	-4.026	0.001

4. Discussion

4.1. Heavy Metal Concentration in Vegetables

Heavy metal concentration varied in the different markets. Lead concentration was higher in morning samples from Gate and Oje and was above the WHO/FAO recommended standard of 0.3mg/kg. This may be due to the high number of vehicles in the area in the mornings. Lead concentration in the evening samples exceeded the WHO/FAO standard were significantly higher than the concentration in the morning samples for all the vegetables sampled. However, only the concentration of lead in ugwu (morning sample) was significantly lower than the standard (0.02mg/kg). Lead being a serious cumulative body poison enters into the body system

through air, water and food and cannot be removed by washing fruits and vegetables [9].

The high concentration of lead in this study may be due to the cultivation methods of the vegetables and the location in which they were cultivated or sold. This is in line with the recent study [10] showing that the high levels of lead in some plants may probably be attributed to pollutants in irrigation water, farm soil or due to pollution from the highways traffic.

However, cadmium concentration in soko and tete were significantly below the WHO/FAO standard (0.2mg/kg). Cadmium concentration in this study is higher than those recorded in previous studies which reported varying levels between 0.003 and 0.09 mg/kg; lowest in pawpaw and highest in fluted pumpkin plant. Various values have been previously reported for fruits and leafy vegetables which include 0.05 mg/kg, 0.14 mg/kg and 0.003 mg/kg for

apple and other fruits [4,7,11]. Cadmium concentration in all the markets exceeded the WHO/FAO recommended standard of 0.2mg/kg and was higher in morning samples from gate and evening samples from Oje. This may be due to the low levels of zinc concentration in the soils where the vegetables were cultivated which leads to an increase in the uptake of cadmium. It may also be due to an increase in the saline concentration of the soils due to irrigation with saline water which also leads to an increased uptake of cadmium by the vegetables. Also, the major source of cadmium is fuel burning, batteries and tire wear, there may be difference in cadmium level due to difference in the population of residents in these localities. The rate at which vehicles (that brings about tire wear, fuel burning, batteries discharge) are utilized differs. [12]. Previous studies acknowledge that most human cadmium exposure comes from ingestion of food, and most of that arises from the uptake of cadmium by plants from fertilizers, sewage sludge, manure and atmospheric deposition, [11,12]. Studies also identified that various sources of environmental contamination have been implicated for the presence of cadmium in foods [12].

This study revealed that zinc concentration in all the samples was well below the WHO/FAO standard (99.4 mg/kg). Zinc concentration levels in soko and ewedu were the highest and ranged between 0.17-0.40mg/kg. Morning concentrations of zinc were significantly higher than evening concentrations in all the vegetable samples. This low concentration of zinc may be because of low levels of zinc in the soil. This is in line with previous studies which showed that concentration of Zn in fruits was low and below the recommended standard and varied between 0.03 mg/kg and 0.13 mg/kg with the lowest in Indian Basil and the highest in plumed cockscomb [14]. Previous literature also shows that the levels of Zn in apple are 1.36 mg/kg, 0.16 mg/kg and 2.05 mg/kg [5,14,15]. It was also reported that Zn levels of 5.35 mg/kg and 7.40 mg/kg; 2.38 mg/kg and 2.20 mg/kg; as well as 5.59 mg/kg and 1.50 mg/kg for watermelon, orange and banana, respectively. The low level of zinc in this study may be attributed to the soil on which the vegetables were grown. Such soil may be sited in rural areas, which may not be contaminated.

Nikel concentration in the evening samples was highest in tete (0.18 mg/kg) and soko (0.15 mg/kg) which also had the highest concentration in the morning samples (0.11 mg/kg). Nikel concentrations in all vegetables were however below the WHO/FAO standard (0.7 mg/kg). Nickel concentration varied in the different markets with evening samples been above the WHO/FAO recommended level of 0.7mg/kg. This may be due to the high traffic density in these areas

The study revealed that Morning samples of soko had the highest concentration of copper (0.4 mg/kg) which was above the WHO/FAO standard (0.2 mg/kg). Evening samples from ugwu (0.22 mg/kg), waterleaf (0.27 mg/kg) and tete (0.25 mg/kg) exceeded the standard. The average copper concentrations in evening samples of the vegetables were significantly higher than the concentration in the morning samples. Mean concentration of copper in all samples from the different markets irrespective of time of the day was above the WHO/FAO recommended standard. Also, copper concentration in samples gotten less than 15km from the road was higher

than the WHO/FAO limit and was higher than those gotten more than 15 km from the road. This aligns with a study [16] which highlighted the presence of copper in soil and its accumulation in the vegetative part of fruits and vegetables consumed by humans.

5. Conclusion

This study revealed that the concentration of heavy metals of some selected common leafy vegetables was higher than recommended WHO/FAO standard except in few cases. The study also showed that the heavy metal concentration in the vegetables exceeds those from previous studies. This may be partly attributed to the geological status of the area under investigation. The values of heavy metals presented in this work from fruits and leafy vegetables obtained from Ibadan, Nigeria can be valuable in the food composition tables for Nigerians and the West African sub-region. Heavy metal depositions are associated with a wide range of sources such as vehicular emissions, suspended road dust/particles, diesel generator sets as well as poor hygiene practices by food vendors and excessive chemical applications by farmers. These can all be important contributors to the contamination found in vegetables.

Recommendations

There is need for an improved food quality assurance system by educating farmers and vegetable vendors on the problems associated with excessive usage of fertilizers and other chemicals, as well as hygiene practices during transportation and display of these vegetables in the market to prevent exposure of vegetables to heavy metals from immediate surroundings. Also, appropriate regulations by state and local government authorities should be put in place by law makers and implementing sanctions for non-compliance. In addition, Local authorities should set up laboratories where samples of leafy vegetables items can be tested for heavy metal concentration. Finally, Compelling supervision of agronomic practices, for example, utilization of manures and utilization of waste water which influence bioavailability and yield gatherings of heavy metals and microbial burden ought to be set up to guarantee the creation of vegetables that are okay for human utilization.

Author's Contributions

The study designs was developed and written by Dada A.O, including the recommendation, while Makanjuola B.C wrote the Introduction and developed the narratives for the results. On the other hand, Adewumi M.O analysed and discussed the results.

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