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Heavy Metal Valuation of Selected Leafy Vegetables Cultivated Around the Otu-Jeremi Axis, Delta State, Nigeria: Implications for Environmental Quality and Food Safety

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ABSTRACT

Environmental pollution arising from industrial activities, urbanization, and agricultural practices has become a major concern worldwide because of its potential effects on environmental sustainability and human health. Among the various environmental contaminants, heavy metals are particularly important due to their persistence, toxicity, and ability to accumulate in living organisms. Leafy vegetables form an essential part of the human diet and are widely consumed in Nigeria; however, they can serve as pathways through which contaminants present in the environment enter the food chain. This study investigated the concentration of selected heavy metals in commonly consumed leafy vegetables cultivated around the Otu-Jeremi axis in Delta State, Nigeria. The vegetables examined included bitter leaf (Vernonia amygdalina), fluted pumpkin (Telfairia occidentalis), waterleaf (Talinum triangulare), and scent leaf (Ocimum gratissimum). A control sample was collected from Ugbomro community, located away from major industrial activities. The vegetable samples were air-dried, pulverized, and subjected to microwave-assisted acid digestion prior to analysis using Atomic Absorption Spectrophotometry (AAS).

The metals analyzed included iron (Fe), copper (Cu), zinc (Zn), chromium (Cr), cadmium (Cd), and lead (Pb). The results showed that Fe concentrations ranged from 0.115–0.227 mg/kg, Cu from 0.005–0.011 mg/kg, and Zn from 0.034–0.050 mg/kg. Chromium, cadmium, and lead were not detected in any of the analysed samples. Statistical evaluation indicated mean concentrations of Fe (0.153 ± 0.044 mg/kg), Cu (0.0084 ± 0.0023 mg/kg), and Zn (0.0412 ± 0.0073 mg/kg). All detected metals were far below the permissible limits recommended by FAO and WHO for vegetables intended for human consumption. The findings suggest that vegetables cultivated within the Otu-Jeremi axis are presently safe for consumption with respect to heavy metal contamination. Nevertheless, considering the ongoing petroleum exploration and industrial activities within the Niger Delta region, continuous environmental monitoring remains essential to ensure long-term food safety.

Keywords: *Heavy metals, leafy vegetables, environmental contamination, Niger Delta, food safety.*

1. Introduction

Environmental contamination has become one of the most significant global challenges of the modern era. Rapid industrialization, urban expansion, petroleum exploration, and intensified agricultural practices have led to the release of various pollutants into soil, water, and air. Among these pollutants, heavy metals have attracted considerable attention because of their persistence in the environment and their potential to accumulate in biological systems. [2].

Unlike many organic pollutants that can be degraded through biological processes, heavy metals are non-biodegradable and may remain in the environment for long periods. When present in soils, they can be absorbed by plants and subsequently transferred through the food chain to animals and humans. Continuous exposure to elevated concentrations of heavy metals has been associated with several adverse health effects, including neurological disorders, kidney damage, and various forms of cancer [11]

Vegetables represent an essential component of human nutrition. They provide important nutrients such as vitamins, minerals, dietary fiber, and antioxidants that contribute to overall health and disease prevention. However, vegetables grown in contaminated environments may accumulate heavy metals through their roots from soil or through deposition on their leaves from atmospheric sources. Leafy vegetables are particularly susceptible to contamination because of their large surface area and rapid growth characteristics. . [3].

In many developing countries, including Nigeria, urban agriculture and small-scale vegetable farming play an important role in food security and household income. Unfortunately, agricultural soils may become contaminated through several pathways, such as industrial emissions, wastewater irrigation, traffic-related pollution, and the application of agrochemicals. As a result, vegetables cultivated in such environments may contain detectable levels of heavy metals.[13].

The Niger Delta region of Nigeria is one of the most environmentally sensitive regions in the country due to extensive petroleum exploration activities. Oil spills, gas flaring, and industrial discharge have contributed to environmental degradation in many parts of the region. Delta State, where this study was conducted, hosts numerous oil production facilities and pipelines. Despite these environmental pressures, local farmers continue to cultivate vegetables for both domestic consumption and commercial sale. .[5].

Vegetables commonly cultivated in the region include bitter leaf (*Vernonia amygdalina*), fluted pumpkin (*Telfairia occidentalis*), waterleaf (*Talinum triangulare*), and scent leaf (*Ocimum gratissimum*). These vegetables are widely used in traditional Nigerian cuisine and form a significant part of daily diets. . [3].

Given the environmental challenges associated with petroleum exploration and industrial activities in the Niger Delta, it is important to assess the levels of heavy metals in food crops cultivated in the region. Such assessments provide valuable information for evaluating potential health risks and ensuring food safety.[8].

Therefore, the present study was designed to determine the concentrations of selected heavy metals in commonly consumed leafy vegetables cultivated around the Otu-Jeremi axis of Delta State. The study also compared the measured concentrations with internationally recommended safety limits to evaluate potential risks associated with vegetable consumption in the study area.

2 Materials and Methods

2.1 Study Area

The study was carried out in the Otu-Jeremi axis located within Ughelli South Local Government Area of Delta State, Nigeria. The region lies within the Niger Delta and experiences a humid tropical climate characterized by high rainfall and relatively high temperatures throughout the year.

Agriculture is one of the major economic activities in the area, with local farmers cultivating a variety of crops including vegetables, cassava, maize, and plantain. However, the region is also influenced by petroleum exploration activities, which may contribute to environmental contamination through oil spills, gas flaring, and industrial emissions.

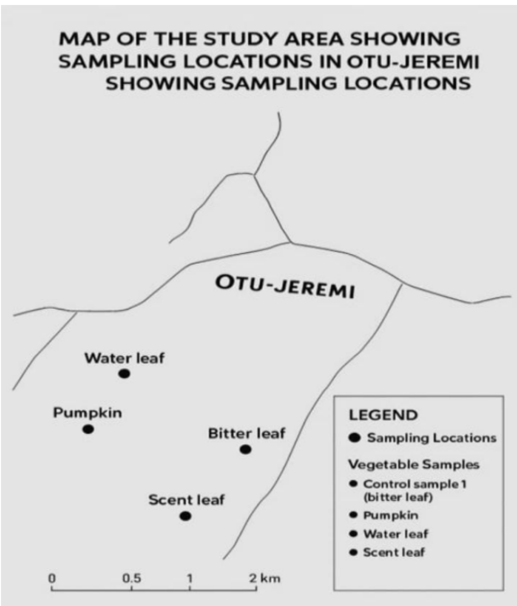

Figure 1: Map of study area showing sampling locations in Otu Jeremi axis

2.2 Sample Collection

Fresh samples of commonly consumed leafy vegetables were collected from farmlands located within the Otu-Jeremi axis. The vegetables selected for analysis included bitter leaf, pumpkin leaf, waterleaf, and scent leaf.

To provide a basis for comparison, a control sample was obtained from Ugbomro community, an area located at a considerable distance from industrial activities.

The samples were carefully harvested using clean stainless-steel tools and immediately placed in labelled polyethene bags. They were then transported to the laboratory for further processing and analysis.

Plate 1: (a) Bitter leaf (Vernonia amygdalina), (b) Waterleaf (Talinum triangulare), (c) Scent leaf (Ocimum gratissimum), and (d) Pumpkin (Telfairia occidentalis).

Source: *Images adapted from Wikimedia Commons*

2.3 Sample Preparation

The vegetable samples were thoroughly washed with distilled water in the laboratory to remove adhering soil particles and other impurities. The samples were then air-dried at room temperature for approximately two weeks until a constant weight was achieved.

The dried samples were subsequently ground into fine powder using a mortar and pestle. The powdered samples were stored in clean airtight containers before digestion and analysis.

Plate 2: Dried leafy vegetable samples (Vernonia amygdalina, Telfairia occidentalis, Talinum triangulare, and Ocimum gratissimum) collected from Otu Jeremi axis and control site (Ugbomro Community).

2.4 Heavy Metal Analysis

Approximately 0.5 g of each powdered sample was subjected to microwave assisted acid digestion using a mixture of nitric acid and hydrogen peroxide. The digestion process ensured complete breakdown of organic matter and release of the metals into solution.

The digested samples were filtered and diluted with deionized water before analysis. The concentrations of iron, copper, zinc, chromium, cadmium, and lead were determined using Atomic Absorption Spectrophotometry (AAS).

3 Results

The concentrations of heavy metals detected in the analyzed vegetables are presented in figure 1.Iron ranged from 0.115–0.227 mg/kg, copper from 0.005–0.011 mg/kg, and zinc from 0.034–0.050 mg/kg. Chromium, cadmium, and lead were not detected in any sample.

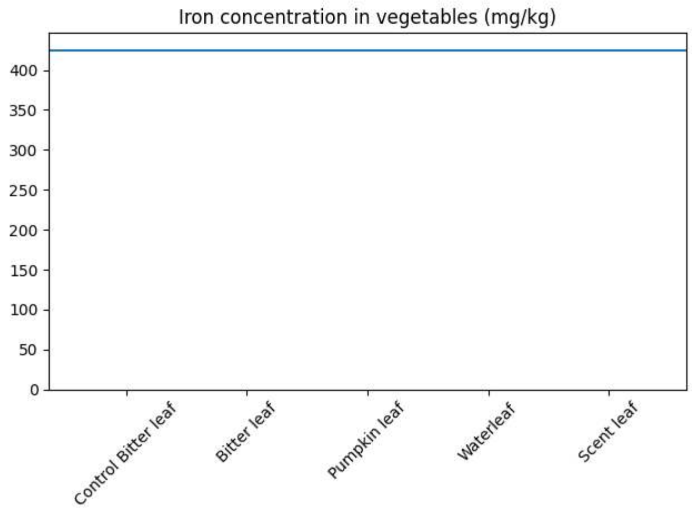

Figure 1: Concentrations of Iron detected in the analyzed vegetables

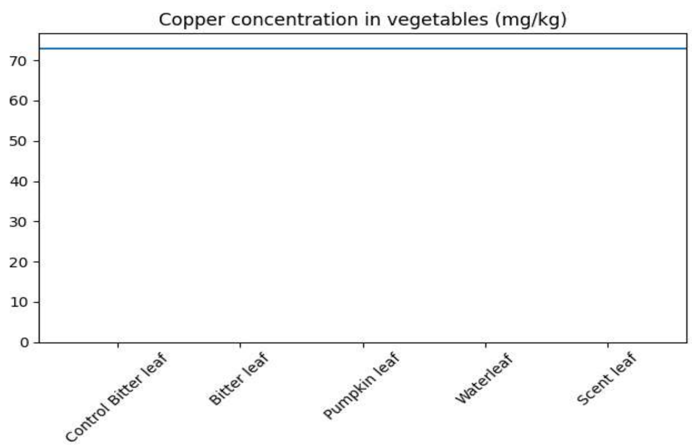

Figure 2: Concentrations of Copper detected in the analyzed vegetables

Copper values varied between 0.005 and 0.011 mg/kg, with the highest concentration observed in Ugu leaf (0.011 mg/kg) and the lowest in Water leaf (0.005 mg/kg). Copper is vital for enzyme activation and physiological processes in both plants and humans. However, excess copper can be toxic. The concentrations detected in all the samples are well below the WHO/FAO permissible limit of 10 mg/kg, indicating that the vegetables are safe for consumption.

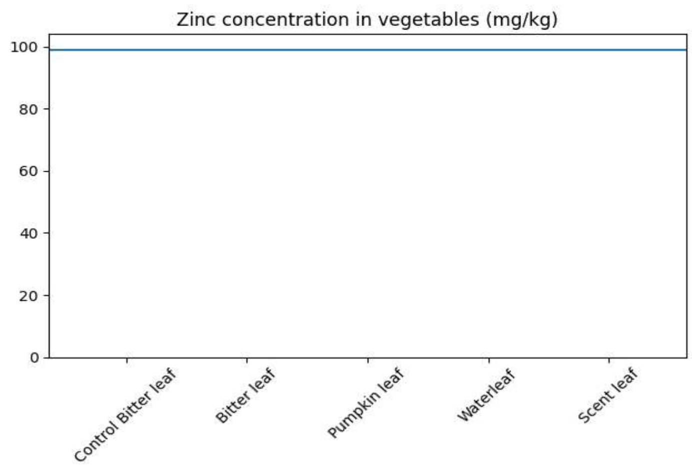

Figure 3: Concentrations of Zinc detected in the analyzed vegetables

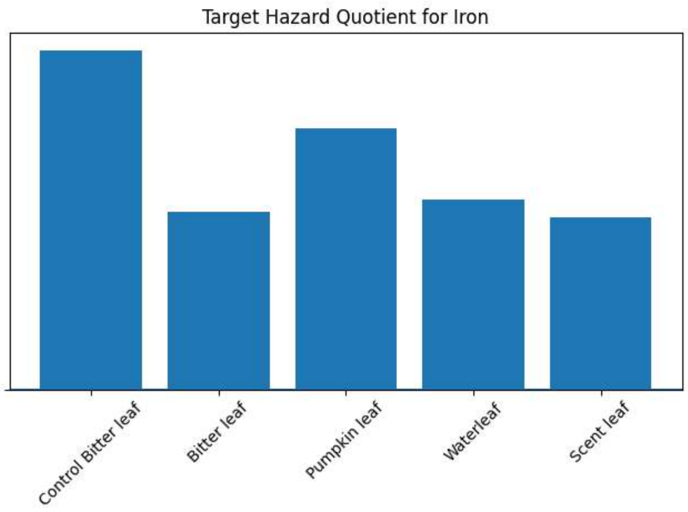

Figure 3: Target Hazard Quotient for Iron

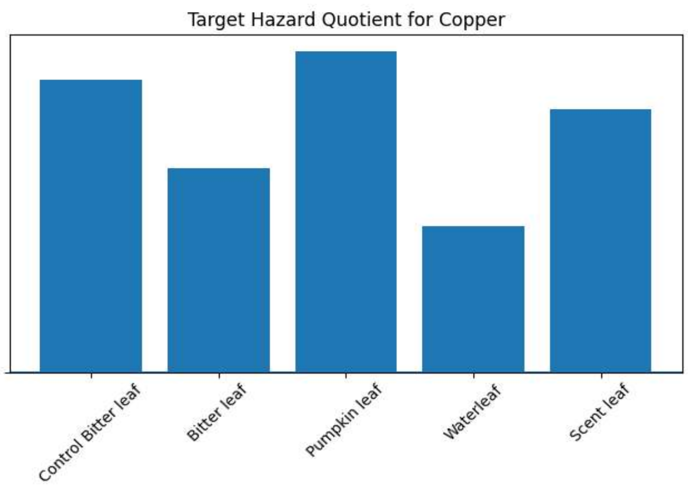

Figure 4: Target Hazard Quotient for Copper

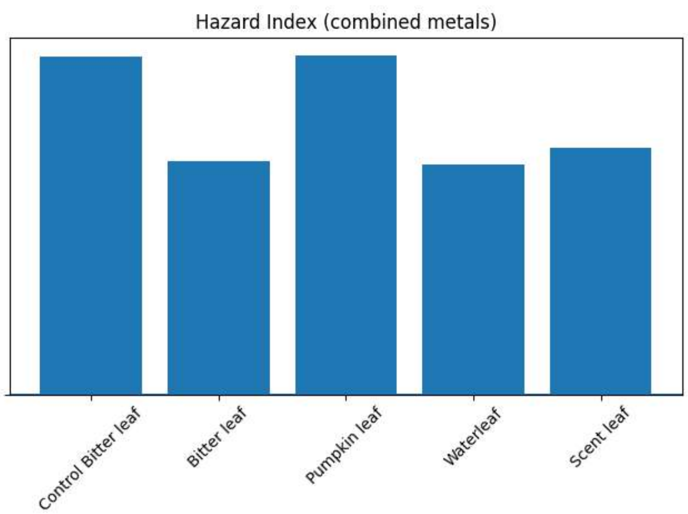

Figure 5: Hazard Index (Combined metals)

Chromium, Cadmium, and Lead were not detected (0.000 mg/kg) in any of the vegetable samples analyzed. The absence of these heavy metals suggests that the vegetables were grown in unpolluted soil and free from anthropogenic contamination.

Table 1: presents the comparison between the observed values and international standards

Metal	Concentration Range (mg/kg)	WHO/FAO Permissible Limit (mg/kg)	Remark
Fe	0.115 – 0.227	425	Below limit
Cu	0.005 – 0.011	40	Below limit
Zn	0.034 – 0.050	60	Below limit
Cr	0.000	1.30	Not detected
Cd	0.000	0.20	Not detected
Pb	0.000	0.30	Not detected

All detected metal concentrations were far below WHO/FAO permissible limits for vegetables. The absence of toxic metals (Cr, Cd, Pb) indicates low contamination levels in the study area.

4. Discussion

The results obtained from this study indicate (Table 1) relatively low concentrations of heavy metals in the analyzed vegetable samples. Iron was the most abundant metal detected in the samples, followed by zinc and copper. This pattern is consistent with previous studies that have reported higher concentrations of essential trace metals compared to toxic metals in agricultural soils and plants.

Iron concentrations ranged from 0.115 to 0.227 mg/kg, with the highest value recorded in the Bitter leaf control (0.227 mg/kg) and the lowest in Scent leaf (0.115 mg/kg). Iron is an essential micronutrient involved in chlorophyll formation and oxygen transport in humans. The values obtained are low but within the acceptable range for leafy vegetables. The lower concentration in test Bitter leaf compared to the control may be due to variations in soil composition, fertilizer use, or differences in environmental exposure (12]

Copper values varied between 0.005 and 0.011 mg/kg, with the highest concentration observed in Ugu leaf (0.011 mg/kg) and the lowest in Waterleaf (0.005 mg/kg). Copper is vital for enzyme activation and physiological processes in both plants and humans. However, excess copper can be toxic. The concentrations detected in all the samples are well below the WHO/FAO permissible limit of 10 mg/kg, indicating that the vegetables are safe for consumption (FAO/WHO, 2019).

Zinc concentrations ranged from 0.034 to 0.050 mg/kg. The Ugu leaf recorded the highest value (0.050 mg/kg), while the Bitter leaf control and Scent leaf showed the lowest (0.034 mg/kg). Zinc is an essential trace element necessary for various metabolic and enzymatic functions. The levels recorded in all samples are within safe limits (<100 mg/kg) and indicate no evidence of environmental or industrial contamination.

Chromium, Cadmium, and Lead were not detected (0.000 mg/kg) in any of the vegetable samples analyzed. The absence of these heavy metals suggests that the vegetables were grown in unpolluted soil and free from anthropogenic contamination. This is significant, as Cd and Pb are highly toxic even at trace levels and can pose serious health risks upon bioaccumulation in the food chain [9].

Among the samples analyzed, Ugu leaf exhibited the highest overall concentrations of essential micronutrients (Fe, Cu, and Zn), making it nutritionally superior. In contrast, Scent leaf recorded the lowest values. The Bitter leaf control contained higher Fe than the test Bitter leaf, possibly reflecting the effect of environmental or cultivation conditions on metal uptake

The low levels of Fe, Cu, and Zn detected, coupled with the non-detection of Cr, Cd, and Pb, indicate that these vegetables are safe for human consumption and pose no heavy metal contamination risk. This also suggests that the cultivation sites are environmentally clean and free from industrial effluents or hazardous waste influence, in line with the finding of [1].

The absence of cadmium and lead in all analyzed samples is particularly significant because these metals are known to pose serious health risks even at low concentrations. Their absence suggests that the soils used for vegetable cultivation in the study area are not heavily contaminated with these toxic elements [4].

Furthermore, the measured concentrations of all detected metals were well below the maximum permissible limits recommended by international food safety organizations such as FAO and WHO. This suggests that the vegetables cultivated in the Otu-Jeremi axis are currently safe for human consumption with respect to heavy metal contamination.

However, it is important to note that the Niger Delta region continues to experience environmental pressures due to petroleum exploration and industrial activities. Continuous monitoring of soil and crop quality is therefore necessary to ensure that contamination levels remain within safe limits.

The low concentrations of essential metals observed reflect natural soil composition rather than anthropogenic pollution. Pumpkin leaf recorded the highest levels of Fe, Cu, and Zn, consistent with its recognized nutritional value. The non-detection of Cr, Cd, and Pb is significant, given their toxicity and persistence in polluted environments. These findings agree with previous studies conducted in southern Nigeria, which reported low heavy metal accumulation in vegetables grown in relatively uncontaminated soils. Although current contamination levels are minimal, continued industrial activities in the Niger Delta necessitate routine environmental monitoring to prevent future health risks [5,6].

Conclusion

The low concentrations of essential metals observed reflect natural soil composition rather than anthropogenic pollution. Pumpkin leaf recorded the highest levels of Fe, Cu, and Zn, consistent with its recognized nutritional value. The non-detection of Cr, Cd, and Pb is significant, given their toxicity and persistence in polluted environments. These findings agree with previous studies conducted in southern Nigeria, which reported low heavy metal accumulation in vegetables grown in relatively uncontaminated soils. Although current contamination levels are minimal, continued industrial activities in the Niger Delta necessitate routine environmental monitoring to prevent future health risks.

Competing Interests Authors have declared that no competing interest exist

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