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Evaluation of Heavy Metal Contamination in *Amaranthus hybridus* (Spinach)

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Abstract

Heavy metals contamination in edible plants poses significant risks to human health and environmental sustainability. This study evaluates heavy metal contamination in *Amaranthus hybridus* L. (spinach) collected from three sites: Nyabunkaka River, Kogin Sarki, and Mayo-Gwoi River in Jalingo, Taraba State, Nigeria. The study aimed to determine the levels of lead (Pb), cadmium (Cd), chromium (Cr), zinc (Zn), copper (Cu), nickel (Ni), manganese (Mn), and cobalt (Co) in spinach samples using Atomic Absorption Spectrophotometry (AAS). Results revealed that Pb concentration in spinach from Nyabunkaka slightly exceeded the FAO permissible limit, while Cd, Cr, Zn, Cu, Ni, Mn, and Co levels in all samples were below FAO reference values, indicating minimal contamination risks. These findings highlight the potential environmental pollution near Nyabunkaka River and suggest that spinach from the selected areas remains largely safe for human consumption, except for slight Pb contamination. The study emphasizes the need for continuous monitoring to ensure food safety.

Keywords: *Amaranthus hybridus*, Heavy Metals, Contamination, Food Safety, Bioaccumulation

INTRODUCTION

Amaranthus hybridus L., commonly known as spinach or pigweed, is a highly nutritious leafy vegetable widely consumed in Nigeria (Bora, 2018; Ogwu, 2020). As a member of the Amaranthaceae family, it serves as both a food source and medicinal plant, valued for its high content of essential nutrients and bioactive compounds (Ekeke *et al.,* 2019; Otorkpa *et al.,* 2019; Ruth *et al.,* 2021). Due to its fast growth and resilience, *A. hybridus* is cultivated in various regions, particularly near rivers and streams, where it thrives in nutrient-rich soils. However, the proximity of cultivation sites to industrial activities and urban runoff raises concerns about contamination, especially by heavy metals, which pose significant health risks to humans (Huber *et al.,* 2016; Kumar *et al.,* 2017; Masindi and Muedi, 2018; Ali *et al.,* 2021).

Heavy metals, such as lead (Pb), cadmium (Cd), chromium (Cr), zinc (Zn), copper (Cu), nickel (Ni), manganese (Mn), and cobalt (Co), are naturally occurring elements that can accumulate in the environment through human activities such as industrial discharge, agricultural runoff, and improper waste management (Mishra *et al.,* 2019; Sandeep *et al.,* 2019). When these metals contaminate agricultural soils, they are absorbed by plants, potentially leading to toxic concentrations in edible crops. Prolonged exposure to heavy metals can have detrimental health effects, including kidney damage, neurological disorders, and cancer (Järup, 2003; Mahurpawar *et al.,* 2015; Rehman *et al.,* 2018; Engwa *et al.,* 2019). The consumption of contaminated vegetables, such as *A. hybridus*, is one of the main pathways through which humans are exposed to these harmful substances (Chia *et al.,* 2019; Ogunkunle *et al.,* 2022).

This study aims to assess the levels of heavy metal contamination in *A. hybridus* grown in Jalingo, Taraba State, Nigeria, focusing on samples collected from three sites: Nyabunkaka River, Kogin Sarki, and Mayo-Gwoi River. The findings were compared to the Food and Agriculture Organization (FAO) permissible limits to determine the safety of consuming spinach from these areas.

METHODS

Sample collection

Fresh *Amaranthus hybridus* (spinach) samples were collected from three locations: Nyabunkaka River (Site 1), Kogin Sarki (Site 2), and Mayo-Gwoi River (Site 3). The collection took place during February and March 2024, coinciding with the dry season. These sites were selected based on their significance as potential pollution sources. The *A. hybridus* samples were handpicked, rinsed with river water to remove sediment, placed in labeled polyethylene bags, and promptly transported to the laboratory where, the samples were thoroughly washed with distilled water to eliminate soil and other contaminants, then dried in an oven at 80°C for 24 hours. After drying, the samples were ground into fine powder using a mortar and pestle. Wet digestion of 1 g sample was performed using 5 mL concentrated nitric acid (Guangdong Guanghua Sci-tech Co), then diluted to 100 ml with distilled water and the digests were filtered through Whatman No. 42 filter paper.

AAS Analysis

A flame atomic absorption spectrophotometer (AAS - Shimadzu AA 7000) was used in the analysis. The concentrations of the metals were determined in triplicates. A series of standards were prepared for instrumental calibration by serial dilution of working solutions (100 mg/l) prepared from analytical grade stock solutions (1000 mg/l) from Sigma and Aldrich INC., USA. For each element, six standard solutions of different concentrations were prepared in 0.1M HNO_3 within a linear concentration range. The calibration curves were prepared for each of the metals investigated by least square fitting. Quality assurance was guaranteed through triple determinations and use of blanks for correction of background and other sources of error.

Data Analysis

Statistical analysis was carried out using SPSS version 27 (IBM, USA). All experiments were conducted in triplicate, and the results expressed as mean ± standard deviation (SD). The concentrations of heavy metals in *Amaranthus hybridus* samples from the three sites were compared using analysis of variance (ANOVA) to determine significant differences ($p < 0.05$) between the means of the different sampling locations.

RESULTS

Table 1: Heavy Metal Concentrations in *Amaranthus hybridus* Samples

Metal	Nyabunkaka (mg/kg)	Mayo-Gwoi (mg/kg)	Kogn Sarki (mg/kg)	Reference (mg/kg)
Pb	0.3086±0.0020	0.2469±0.0020	0.1852±0.0010	0.3000
Cd	0.0311±0.0020	0.0055±0.0010	0.0128±0.0020	0.2000
Cr	0.0080±0.0020	0.0050±0.0010	0.0060±0.0020	2.3000
Zn	1.2000±0.0020	1.0000±0.0010	1.1000±0.0020	100.0000
Cu	0.1111±0.0020	0.1185±0.0020	0.0889±0.0010	40.0000
Ni	0.3000±0.0020	0.2000±0.0010	0.2000±0.0010	1.5000
Mo	0.1300±0.0010	0.2200±0.0020	0.2500±0.0020	500.0000
Co	0.0260±0.0010	0.0390±0.0020	0.0350±0.0010	50.0000

The heavy metal concentrations in spinach samples harvested from Nyabunkaka River, Kogin Sarki River, and Mayo-Goi River are shown in Table 1 and the amounts of heavy metals are compared to reference limits set by the Food and Agriculture Organization (FAO, 2011; Åkesson *et al.,* 2015).

The results shows that lead concentration in spinach from Nyabunkaka River slightly exceeds the FAO permissible limit (0.3 mg/kg). Although Kogin Sarki and Mayo-Goi River samples remain below the reference value, the slight exceedance in Nyabunkaka suggests potential contamination, likely due to environmental pollution. While the remaining heavy metals remain at well below the FAO limit.

DISCUSSION

Prior research has indicated that exposure to lead might cause health hazards such as renal damage and cognitive impairment (Chatha *et al.,* 2023). Variable Pb levels in leafy vegetables have been documented in similar investigations conducted in different countries. For example, Akinola *et al.* (2018) showed that lead levels in Lafiya, Nasarawa State, Nigerian vegetables ranged from 0.15 to 0.35 mg/kg, which is consistent with the modest excess noted in spinach from the Nyabunkaka River.

All three rivers' cadmium concentrations in *A. hybridus* are far lower than the FAO's recommended level of 0.2 mg/kg, indicating a low risk of cadmium toxicity. These findings align with those of Khan *et al.* (2008), who observed low amounts of cadmium in leafy crops irrigated with effluent from Beijing, China. The low Cd levels here are reassuring, as high cadmium ingestion can lead to kidney impairment and other health issues.

Chromium levels being well below the threshold is consistent with findings from a study in Egypt by Osman and Kloas (2010), where vegetables grown near the River Nile also showed low chromium contamination. The minimal Cr content suggests limited exposure to industrial pollutants known to contribute to higher Cr levels in the environment.

Zinc levels in *A. hybridus* from all rivers are well below the FAO permissible limit of 100 mg/kg. Zinc, though an essential trace element, can become toxic at high levels. These low concentrations indicate that there is no significant zinc contamination in spinach from these areas. Similar findings were reported in a study from Egypt, where Shinnawi and El-Gamel (2017) observed similarly low zinc concentrations in vegetables irrigated with wastewater.

Copper concentrations in *A. hybridus* from all three rivers are significantly lower than the FAO permissible limit of 40 mg/kg. This is consistent with a study conducted in Lafiya, Nasarawa State, by Akinola *et al.* (2018), where copper levels in vegetables ranged between 0.05 and 0.20 mg/kg. While copper is necessary for human health, excessive levels can cause liver and kidney damage (Fraga, 2005). The levels observed here are far below toxic levels, suggesting no risk from copper exposure.

Nickel levels in *A. hybridus* from all rivers are well below the FAO reference value of 1.5 mg/kg, indicating that there is no significant nickel contamination. High nickel levels can lead to allergic reactions and other health concerns (Das *et al.,* 2008). Previous studies, such as those conducted by Shinnawi and El-Gamel (2017) in Egypt, have also reported low nickel levels in vegetables, supporting the findings in this analysis.

Manganese concentrations in *A. hybridus* from all rivers are significantly lower than the FAO reference value of 500 mg/kg, implying no risk of manganese toxicity. Manganese is an essential element but can cause neurological problems at high levels (Santamaria, 2008). These findings are consistent with Alloway (2013), who also reported low manganese levels in vegetables from various regions.

Cobalt levels in all *A. hybridus* samples are well within the FAO permissible limit of 50 mg/kg. Cobalt is an essential trace element for vitamin B12 synthesis, but excessive amounts can be harmful (Palit *et al.,* 2014). The results here align with previous research from Khan *et al.* (2024), which also reported low cobalt levels in edible vegetables.

CONCLUSION

In conclusion, except for lead (Pb) in the Nyabunkaka River, the examination of heavy metal concentrations in *A. hybridus* from the Kogin Sarki, Mayo-Goi, and Nyabunkaka Rivers shows that all other metals are under the FAO-approved levels, suggesting no risk of heavy metal toxicity. Lead levels in Nyabunkaka that are marginally above the FAO reference value point to a possible contamination risk that is probably caused by human activity. This emphasizes the necessity of more frequent environmental monitoring and intervention.

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