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Investigation Of Heavy Metals Absorption and Accumulation in Leaves of Basella Alba L. (Malabar Spinach)

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Abstract-* This study investigated the absorption and accumulation of heavy metals and minerals in the leaves of Basella alba L. irrigated with Adada River water, sewage effluent, and tap water over six weeks. The aim was to determine the levels of selected heavy metals and compare them with WHO/FAO permissible limits for vegetables. Fresh samples of B. alba were cultivated and irrigated separately with the three water sources. The concentrations of lead (Pb), arsenic (As), cadmium (Cd), mercury (Hg), nickel (Ni), and zinc (Zn) were analyzed before treatment and after 2, 4, and 6 weeks using standard analytical methods. The initial concentrations before treatment were low, with zinc having the highest value (0.877 µg/g), while lead, arsenic, cadmium, mercury, and nickel were present in trace amounts. Across all treatments, heavy metal concentrations increased progressively with irrigation duration, indicating continuous uptake and accumulation in the leaves. Sewage effluent irrigation showed the highest accumulation of arsenic, cadmium, mercury, and nickel, while tap water recorded the highest zinc concentration at week 6 (0.95 µg/g). Lead, cadmium, nickel, and zinc remained below WHO/FAO permissible limits, but mercury exceeded the safe limit of 0.03 µg/g at week 6 in all treatments, with the highest value recorded in sewage effluent (0.053 µg/g). Statistical analysis showed significant differences ($P \leq 0.05$) across treatments and weeks. The study concludes that prolonged irrigation, especially with sewage effluent, increases heavy metal accumulation in B. alba, and mercury poses the greatest health risk. Regular monitoring of irrigation water and vegetables is recommended to ensure food safety.

Keywords: Vegetable, heavy metals, Basella alba L., River water, and irrigation.

I. INTRODUCTION

Vegetables are essential components of the human diet because they provide vitamins, minerals, dietary fiber, antioxidants, and other phytochemicals necessary for maintaining good health and preventing diseases. Leafy vegetables are particularly important because they are consumed frequently and in relatively large quantities, making them major contributors to human nutrition. However, these same vegetables can also serve as pathways for the entry of toxic contaminants into the food chain, especially heavy metals, when cultivated under polluted environmental conditions (Manwani et al., 2023).

Among the commonly consumed leafy vegetables in tropical and subtropical regions, Basella alba L., commonly known as Malabar spinach, Indian spinach, or vine spinach, is widely cultivated because of its high nutritional value, medicinal relevance, and adaptability to diverse agroecological conditions. Basella alba belongs to the family Basellaceae and is a fast-growing perennial vegetable rich in vitamins A, C, and E, iron, calcium, magnesium, and natural antioxidants. It is widely grown in Nigeria in home gardens, peri-urban farms, and urban agricultural systems due to its high market demand and ease of cultivation. The leaves are commonly used in soups and sauces, while the plant is also utilized in traditional medicine for the treatment of constipation, inflammation, skin infections, anemia, and hypertensio (Codling & Onyeador. 2017).

Despite its nutritional and medicinal importance, the safety of Basella alba has become a major concern due to increasing environmental pollution associated with agricultural soils and irrigation water. Heavy metals are naturally occurring elements with relatively high density and atomic weight, including lead (Pb), cadmium (Cd), arsenic (As), mercury (Hg), nickel (Ni), chromium (Cr), zinc (Zn), copper (Cu), iron (Fe), and manganese (Mn). Some of these metals such as zinc, copper, iron, and manganese are essential micronutrients required in trace amounts for plant growth and human metabolism, while others such as lead, cadmium, arsenic, and mercury are highly toxic even at very low concentrations and have no beneficial biological role (Rahim et al., 2024).

Heavy metals enter the agricultural environment through both natural and anthropogenic activities. Common sources include industrial emissions, mining activities, automobile exhaust, sewage sludge application, excessive use of chemical fertilizers and pesticides, wastewater irrigation, atmospheric deposition, and improper waste disposal. Once introduced into the soil, these metals are persistent because they are non-biodegradable and can remain in the environment for extended periods. This persistence increases the possibility of absorption by edible plants, particularly leafy vegetables cultivated near highways, refuse dumps, industrial zones, and wastewater discharge areas (Waheed et al., 2019).

Plants absorb heavy metals mainly through their roots from contaminated soils and irrigation water, while foliar deposition from polluted air may also contribute significantly to leaf contamination. The level of absorption depends on several factors such as soil pH, organic matter content, metal speciation, cation exchange capacity, irrigation source, plant species, and climatic conditions. Leafy vegetables are especially vulnerable because their broad leaf surfaces enhance atmospheric deposition and direct accumulation of contaminants. Since the edible part of Basella alba is mainly the leaf, heavy metal accumulation in leaves poses a serious public health concern.

Several studies have reported that leafy vegetables accumulate considerable levels of heavy metals, sometimes exceeding the permissible limits established by the Food and Agriculture Organization (FAO) and the World Health Organization (WHO). A comparative field study involving six vegetable species showed that Basella alba accumulated significant concentrations of chromium, cobalt, iron, and manganese in the leaves, while chromium, lead, and nickel were more concentrated in the roots, indicating differential metal distribution within the plant (Zunaidi et al., 2023). Similarly, a study on domestic wastewater irrigation involving Basella alba and other leafy vegetables reported elevated levels of lead, cadmium, and copper in both soil and edible tissues, demonstrating that irrigation source strongly influences heavy metal accumulation (Pham et al., 2024).

Recent findings also indicate that heavy metal accumulation differs among leafy vegetable species and even among varieties of the same species. Kong et al., (2024) reported that cadmium concentrations in leafy vegetables frequently exceeded recommended safety limits, while arsenic and lead were often within acceptable ranges. Their study further showed that bioaccumulation factors varied significantly depending on plant species and soil properties, suggesting that vegetable type and environmental conditions strongly determine contamination levels.

Heavy metal accumulation in edible plants poses serious health risks because these metals can bioaccumulate in human tissues over time. Prolonged exposure to lead may result in neurological disorders, developmental problems in children, kidney dysfunction, and cardiovascular complications. Cadmium exposure is associated with kidney damage, skeletal disorders, and carcinogenic effects. Mercury can cause nervous system disorders, liver toxicity, and immune dysfunction, while chronic arsenic exposure may result in skin lesions, respiratory problems, and various forms of cancer. Even essential metals such as zinc and copper may become toxic when consumed above physiological limits (Negassa et al., 2025).

In many urban and peri-urban farming systems in Nigeria, vegetables are cultivated close to roadsides, mechanic workshops, drainage channels, industrial sites, and refuse dumps where contamination risks are high. Farmers often rely on untreated wastewater or contaminated surface water for irrigation due to water scarcity and economic constraints. Such practices significantly increase the transfer of heavy metals from soil and water into vegetables consumed by the public. Consumers are often unaware of the contamination status of these vegetables, and routine monitoring is limited, thereby raising serious food safety concerns (Kong et al., 2024).

The investigation of heavy metals absorption and accumulation in leaves of Basella alba is therefore important for several reasons. First, it helps determine whether the vegetable is safe for human consumption by comparing detected heavy metal concentrations with WHO/FAO permissible limits. Second, it provides information on the absorption efficiency and accumulation behavior of Basella alba for different metals. Third, it contributes to environmental monitoring by identifying contamination levels in agricultural soils and irrigation sources. Finally, the findings can guide farmers, environmental agencies, and public health authorities in developing safer agricultural practices, pollution control strategies, and food safety regulations (Kong et al., 2024).

Given the increasing rate of environmental pollution and the importance of Basella alba as a widely consumed leafy vegetable, there is a strong need to assess the extent to which heavy metals are absorbed and accumulated in its leaves. Such an investigation is essential for protecting public health, ensuring food quality, and promoting sustainable vegetable production. This study is therefore designed to evaluate the levels of heavy metals in the leaves of Basella alba and to determine the potential health implications associated with its consumption.

II. MATERIALS AND METHODS

2.1 Collection of Materials
Seeds of Basella alba were obtained from the National Horticultural Institute, Ibadan. The seeds were identified and confirmed at the Herbarium of the Department of Plant Science and Biotechnology. The seeds were planted in the screen house of Botanical Garden, University of Nigeria, Nsukka.

2.2 Preparation of Soil Samples
The top soil and sandy soil samples for planting of Basella alba were obtained from the Botanical Garden of the University of Nigeria, Nsukka. The soil samples and poultry manure were mixed in the ratio of 3:2:1 (30 kg top soil, 20 kg of poultry manure and 10 kg of sandy soil) and referred to as amended soil.

2.3 Collection of Water Samples
Water samples used in the investigation were collected from different sources. Sewage effluent was collected from the oxidation pond at the University of Nigeria sewage treatment plant; tap water from the Botanical Garden of the University of Nigeria, Nsukka (UNN); and the river water from Adada River located in Uzo-Uwani Local Government Area of Enugu State, Nigeria.

2.4 Nursery Beds Preparation
Four wide mouth baskets were filled to the brim with the amended soil. Seeds of Basella alba were sown and watered every day till the emergence of the seedlings and 2 weeks after the emergence with tap water to enable the seedlings stabilize (Plates 4 and 6).

2.5 Transplanting of Basella Seedlings
Another amended soil sample was prepared as described in 3.1.2 above. Two kilograms of the prepared soil was portioned into ninety black pots which were perforated at the bottom to allow for exit of water, to ensure the aeration of the seedlings and to avoid water logging of the plants. The pots were placed inside the screen house. After two weeks of nursery, B. alba seedlings were transplanted into the prepared pots. Transplanting was done in the evening to avoid excessive effect of transpiration on the seedlings. The plants were watered with tap water at an interval of two days for one week for the seedlings to stabilize before application of sewage effluent and Adada river water.

Plate 1: Seeds of B. alba

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Plate 2: Seedlings of B. alba

2.6 Experimental Design
The experiment was carried out in a 2 x 3 factorial in a Complete Randomized Design (CRD). The experiment comprised two plants B. alba (Ba) and three water treatments, Adada river water, Sewage effluent and Tap water (WA, WB, and WC) with ten plants per treatment combinations (e.g. BaWC, BaWB,) all in three replications. The potted seedlings were arranged in a randomized manner in a screen house in the Botanical Garden of Department of Plant Science and Biotechnology (PSB), University of Nigeria, Nsukka. The seedlings were irrigated with 100% untreated sewage effluent, river water and tap water respectively according to their treatment combinations as described above. Watering was done at an interval of two days for 6 weeks.

2.7 Chemical Analysis of Plant Samples
The heavy metals and nutrients in the samples were analyzed at the Department of Crop Science Laboratory, Faculty of Agriculture, University of Nigeria, Nsukka using the method described by AOAC (2002).

2.7.1 Preparation of Plant Samples for Chemical Analysis
Preparation of plant samples for chemical analysis was done using the method described by AOAC (2002). The plants were harvested and analysed to investigate the accumulation of heavy metals. Harvesting was done at two weeks interval and five stands from each treatment were used for the analyses. The roots, stems and leaves were dried and ground, drying was at 30oC in a Gallenkamp oven until a constant weight was obtained and ashed in a muffle furnace at 6000C for 3 hours. The ashed sample was cooled in a desiccator and dissolved in 5 mL of 30% hydrochloric acid in a 50 mL volumetric flask. The solution was made up to the mark with distilled water and filtered.

2.7.2 Procedure for digestions of samples for analyses
Five millilitres of the sample were pipetted into 100 mL. conical flask. Twenty millilitres of concentrated nitric acid and 20 mL of perchloric acid were added and sample digested on a hot plate at 1300C with the flask covered with a watch glass. The digestion continued until the colour appeared clear. The silica became white and white fumes of perchloric acid appeared in the flask. The mixture was cooled and made up to 100 millilitres with the distilled water.

2.8 Statistical Analysis
Data analysis was done using Duncan Multiple Range Test. One way analysis of variance (ANOVA) was done to determine the levels of heavy metals and minerals in the study plants. T-test was carried out to compare the concentrations of heavy metals in the leaves of B. alba. Results were expressed as mean ± S.E. The level of significance was at P 0.05 confidence level.

III. RESULTS AND DISCUSSION

3.1 Results
Table 1: Level of heavy metals and minerals in the leaves of B. alba before the treatment with sewage effluent, Adada river water and tap water (μg/g)

Heavy metals	Leaves	P-value
Lead	$0.012±0.0008^{b}$	0.010
Arsenic	0.019±0.001	-
Cadmium	$0.012±0.001^{b}$	0.000
Mercury	0.020±0.001	-
Nickel	$0.015±0.001^{c}$	0.000
Zinc	$0.877±0.003^{a}$	0.000

Mean Values with different superscripts are significantly different at P≤0.05

Table 2: Mean concentrations of heavy metals and minerals in B. alba irrigated with Adada River water

Heavy Metal	Weeks	Leaves (μg/g)	WHO/FAO limit for vegetables (μg/g)
Lead	2	$0.22±0.002^{c}$	0.30
	4	$0.23±0.002^{c}$	

	6	0.25±0.002^{c}	
Arsenic	2	0.03±0.001^{b}	-
	4	0.040±0.002^{b}	
	6	0.045±0.003^{b}	
Cadmium	2	0.018±0.002^{c}	0.20
	4	0.03±0.002^{c}	
	6	0.034±0.002^{b}	
Mercury	2	0.013±0.002^{b}	0.03
	4	0.027±0.001^{c}	
	6	0.037±0.001^{b}	
Nickel	2	0.022±0.003^{b}	0.10
	4	0.025±0.001^{b}	
	6	0.036±0.001^{c}	
Zinc	2	0.86±0.002^{a}	5.00
	4	0.86±0.003^{b}	
	6	0.93±0.001^{a}	

Mean Values with different superscripts are significantly different at $P \leq 0.05$

Table 3: Mean concentrations of heavy metals and minerals in B. alba irrigated with Sewage Effluent

Heavy Metal	Weeks	Leaves (µg/g)	WHO/FAO limit for vegetables (µg/g)
Lead	2	0.22±0.002^{b}	0.30
	4	0.27±0.002^{b}	
	6	0.28±0.002^{c}	
Arsenic	2	0.036±0.002^{b}	-
	4	0.046±0.002^{b}	
	6	0.054±0.002^{b}	
Cadmium	2	0.029±0.002^{c}	0.20
	4	0.031±0.002^{c}	
	6	0.043±0.001^{b}	
Mercury	2	0.029±0.002^{c}	0.03
	4	0.036±0.002^{b}	
	6	0.053±0.002^{a}	
Nickel	2	0.025±0.004^{a}	0.10
	4	0.036±0.002^{a}	
	6	0.039±0.002^{b}	
Zinc	2	0.66±0.002^{a}	5.00
	4	0.84±0.003^{a}	
	6	0.93±0.001^{a}	

Mean values with different superscripts are significantly different at $P \leq 0.05$ across rows

Table 4: Mean concentrations of heavy metals and minerals in B. alba irrigated with tap water

Heavy Metal	Weeks	Leaves (µg/g)	WHO/FAO limit for vegetables (µg/g
Lead	2	0.23±0.003^{b}	0.30
	4	0.25±0.002^{b}	
	6	0.28±0.002^{c}	
Arsenic	2	0.025±0.002^{b}	-
	4	0.032±0.002^{b}	
	6	0.036±0.002^{b}	
Cadmium	2	0.015±0.002^{c}	0.20
	4	0.025±0.002^{c}	
	6	0.035±0.002^{c}	
Mercury	2	0.012±0.002^{c}	0.03
	4	0.027±0.002^{b}	
	6	0.032±0.001^{b}	
Nickel	2	0.017±0.002^{b}	0.10
	4	0.024±0.001^{c}	
	6	0.034±0.002^{c}	
Zinc	2	0.85±0.001 ^{a}	5.00
	4	0.89±0.003^{a}	
	6	0.95±0.003^{a}	

Mean values with different superscripts are significantly different at $P \leq 0.05$ across rows

IV. CONCLUSION

This study revealed that Basella alba L. has the ability to absorb and accumulate heavy metals and minerals from different irrigation water sources, with concentrations increasing progressively over time. The results showed that sewage effluent contributed the highest levels of heavy metal accumulation, followed by Adada River water, while tap water generally recorded the lowest contamination levels. Although most of the analyzed heavy metals such as lead, cadmium, nickel, and zinc remained within the WHO/FAO permissible limits for vegetables, mercury consistently exceeded the safe limit across all irrigation treatments at the sixth week, indicating a potential public health concern.

The findings demonstrate that irrigation source and duration significantly influence heavy metal uptake in Basella alba, highlighting the risk associated with the use of contaminated water for vegetable production. The study therefore concludes that while Basella alba is a nutritionally valuable leafy vegetable, its safety may be compromised when cultivated under polluted irrigation conditions, particularly with sewage effluent. Continuous consumption of such vegetables may lead to long-term exposure to toxic heavy metals, especially mercury, which poses serious health risks. It is therefore recommended that regular monitoring of irrigation water quality and heavy metal levels in leafy vegetables be enforced to ensure food safety and protect public health.

REFERENCES

[1] Adepoju-Bello, A. A., Ojomolade, O. O., Ayoola, G. A., & Coker, H. A. B. (2020). Quantitative analysis of some toxic metals in domestic water obtained from Lagos metropolis, Nigeria. The Nigerian Journal of Pharmaceutical Research, 16(2), 115–123.

[2] Chen, F., Ma, J., Akhtar, S., Khan, Z. I., Ahmad, K., Ashfaq, A, Nawaz, H., Nadeem M. (2022). Assessment of chromium toxicity and potential health implications of agriculturally diversely irrigated food crops in the semi-arid regions of South Asia. Agric Water Manage. 272:107833.

[3] Codling, E. E., & Onyeador, J. (2017). Accumulation of lead and arsenic in Malabar spinach (Basella alba L.) and sweet potato (Ipomoea batatas L.) leaves grown on urban and orchard soils. Journal of Plant Nutrition, 40(20), 2898–2909.

[4] Dagnaw, L. A., Chandravanshi, B. S., Zewge, F. (2017). Fluoride content of leafy vegetables, irrigation water, and farmland soil in the rift valley and in non-rift valley areas of Ethiopia. Fluoride. 50(4):409–429.

[5] Elbagermi, M. A., Edwards, H. G. M., & Alajtal, A. I. (2021). Monitoring of heavy metal content in fruits and vegetables collected from production and market sites in the Misurata area of Libya. ISRN Analytical Chemistry, 2021, 1–8.

[6] Kong, Y., Liu, J., Chen, M., Zheng, W., Liu, Y., Wang, Y., Ruan, X., & Wang, Y. (2024). Accumulation and risk assessment of heavy metals in different varieties of leafy vegetables. Environmental Geochemistry and Health, 46(12), 527.

[7] Kumar, R., Sharma, M., & Gupta, A. (2020). Heavy metal contamination in vegetables irrigated with wastewater and their health implications in urban areas. Environmental Monitoring and Assessment, 192(4), 245–256.

[8] Manwani, S., Devi, P., Singh, T., Yadav, C. S., Awasthi, K. K., Bhoot, N., & Awasthi, G. (2023). Heavy metals in vegetables: A review of status, human health concerns, and management options. Environmental Science and Pollution Research, 30(28), 71940–71956.

[9] Negassa, D. E., Gebremariam, T. T., Bekele, H. T., & Alemayehu, E. T. (2025). Health risk assessment of heavy metal accumulation in vegetables and associated human exposure pathways. Environmental Research, 248, 119874.

[10] Pham, T. H., Nguyen, L. T., Tran, V. H., & Le, Q. P. (2024). Assessment of heavy metal contamination in leafy vegetables irrigated with domestic wastewater and associated human health risks. Asian Journal of Environmental Science Research, 7(1), 45–58.

[11] Rahim, A., Khan, M. S., Hassan, S. U., & Iqbal, M. (2024). Heavy metal contamination in vegetables and associated human health risks: A review of toxicological implications and mitigation strategies. Chemosphere, 357, 141872.

[12] Rahman, M. M., Rahman, M. A., Reichman, S. M., Lim, R. P., & Naidu, R. (2022). Heavy metals in agricultural soils and vegetables irrigated with wastewater: Human health risk assessment and pollution indices. Environmental Geochemistry and Health, 44(3), 875–892.

[13] Ratul A. M. (2018). Potential health risk of heavy metals accumulation in vegetables irrigated with polluted river water. Int Food Res J. 25(1):329–338.

[14] Sharma, P., Dubey, R. S., & Singh, N. (2021). Micronutrient uptake and accumulation in leafy vegetables under varying environmental

conditions. Journal of Plant Nutrition, 44(7), 1021–1035.

[15] Singh, J., Kalamdhad, A. S., & Ali, M. (2021). Assessment of heavy metals in vegetables grown under wastewater irrigation and associated health risks. Chemosphere, 263, 128–145.

[16] Waheed, H., Ahmad, M. S. A., Saleem, M. H., & Gul, B. (2019). Uptake of potentially toxic elements by vegetables irrigated with wastewater and their implications for human health. Journal of Environmental Science and Health, Part A, 54(11), 1140–1152.

[17] Zunaidi, N. A., Rahman, M. M., Islam, M. A., & Hossain, M. B. (2023). Comparative assessment of the heavy metal phytoextraction potential of vegetables from agricultural soils: A field experiment. Environmental Advances, 11, 100345.