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Bioaccumulation of Heavy Metals in Soils, *Talinum triangulare* and *Celosia argentea* Leaves Grown around Temboga Riverbank, Benin City Nigeria

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Abstract

Heavy metal levels in soils may result in heavy metal entry into the food chain, the study aimed at accessing concentration of heavy metals (Cd, Ni, Pb) in soils, *Talinium triangulare* and *C. argentea* leaf grown along Temboga Riverbank in Benin City Edo State Nigeria. Surface (0-15 cm) soil, *T. triangulare* and *C. argentea* leaf samples were collected randomly from Temboga Riverbank (RB), 60 meters from RB (60MRB) and 120 meters from RB (120MRB) in three replicates, making a total of nine soil, nine *T. triangulare* and nine *C. argentea* leaves samples. The soil, *T. triangulare* and *C. argentea* leaves samples were analyzed for some heavy metal properties using standard laboratory methods. The result showed that Cd contents of the soils was highest (0.19 mg kg^{-1}) at 60MRB, however the levels of soil Cd and Ni, were still within tolerance levels in other locations. The results also showed that Cd content of 0.93 mg kg^{-1} obtained for *T. triangulare* leaf at 60 MRB have reached toxic levels, while Cd content of *T. triangulare* leaf at RB (0.77 mg/kg) and 120MRB (0.77 mg/kg) could reach toxic levels in a short time. The Ni levels of *T. triangulare* and *C. argentea* leaves have exceeded permissible limit with values of 4.42, 2.32, 2.22 mg kg^{-1} and 2.88, 2.88, 2.72 mg kg^{-1} recorded at RB, 60MRB, 120MRB respectively. The vegetables (*T. triangulare* and *C. argentea*) leaves could be said to contain toxic levels of Ni and thus unfit for human consumption.

Keywords: Cadmium, Lead, Nikel, Toxic level, Vegetables

Introduction

Heavy metal bioaccumulation may have carcinogenic effects and serious health risks to humans through food chain (Smart *et al.,* 2023). Contamination of agricultural soils with heavy metals has become a critical global environmental issue, particularly in regions where farming occurs near riverbanks, industrial zones, or waste disposal sites (Ahmed *et al*., 2023) Heavy metals maybe non-biodegradable and can persist in the environment, leading to accumulation in soil and eventual uptake by crops (Adewale *et al.*, 2022). In recent years, urban horticulture has become crucial for promoting food security, economic resilience, social well-being, and environmental sustainability. As in many parts of Africa, vegetable farming along wetlands and riverbanks is commonly practiced; however increased urbanization has introduced a range of human activities that contribute to water, soil and plant contamination, ultimately resulting in accumulation of harmful substances in edible parts of crops grown in polluted environments (Hu *et al*., 2023). Riverbank farming is

especially vulnerable to contamination due to deposition of polluted sediments and use of water sources that may carry industrial effluents and or mining runoff (Lisetskii and Buryak, 2023). Vegetables grown in such environments, particularly leafy greens like *Amaranthus hybridus, Talinum triangulare* and *Celosia argentea* amongst others, are known for their high metal uptake capacity, which exacerbates the potential for dietary exposure (Smart *et al.,* 2023). Leaf vegetables are major part of human platter as they have high amounts of fibers, minerals, vitamins, and antioxidants (Kumar *et al.,* 2020). Thus, heavy metals content of vegetables cannot be ignored due to their significance in food quality assurance, understanding the levels and patterns of heavy metal accumulation in riverbank soils and crops is essential for risk assessment, environmental protection, and public health policy as there is dearth of information on heavy metals status in soils, *Talinum triangulare* and *Celosia argentea* leaves grown around river banks in Benin City Nigeria, hence this study aimed at evaluating bioaccumulation of some heavy metals (Cd, Ni, Pb) in soils, *T. triangulare* and *C. argentea* leaves grown around Temboga riverbank in Benin City Nigeria,.

Materials and Methods

The study was carried out where vegetables are cultivated for commercial purpose around

Temboga riverbank in Benin metropolis, Edo state, Nigeria, to evaluate heavy metal content of soils, *T. triangulare* and *C. argentea* leaves, grown around Temboga river bank. The area falls within tropical climate, with average annual rainfall, temperature and relative humidity of 1900 mm, 23-37 °C and 89-75% respectively (NIFOR, 2018). It lies between latitude 6.372510 °N and longitude 5.646745 °E, sloppy and swampy closest to the river and planted to various vegetables, including *T. triangulare*, *C. argentea, Telfaira occidentalis*, *Amaranthus hybridus*, *Capsicum annuum* and *Ocimum gratissimum* (scent leaf), with a history of fertilizers (organic, inorganic) and herbicide use. The soils are developed from coastal plain sand parent material, with intense weathering resulting from high precipitation and temperature (Okunsebor *et al.,* 2024).

Sample collection

Auger surface (0- 15 cm) soil, *T. triangulare* and *C. argentea* leaves samples were collected from Temboga riverbank, 60 and 120 meters away from the riverbank in three replicates, for laboratory analysis in the month of April 2025. Soil samples were air-dried, ground with wooden mortal and sieved through a 2 mm sieve, *T. triangulare* and *C. argentea* leaves were harvested, prepared, grind in a ceramic mortal and passed via a 0.50 mm sieve. The soil, *T. triangulare* and *C. argentea* samples were stored for analysis of some physical and chemical properties in the laboratory.

Soil Analysis

The soils were fractionated and quantified for sand, silt and clay by hydrometer method (Bouyocuos, 1951), while texture was determined by textural triangle (Soil survey staff, 1999b), pH in soil:water (1:2) suspension was measured by glass electrode pH meter (Tan, 1996), Organic carbon by wet oxidation method (Walkley and Black, 1934), exchangeable base (Ca^{2+} + Mg^{2+}) and acid (Al^{3+} + H^{+}) cations were extracted with 1 M NH_4OAc and 1 M KCl, and quantified by 0.01 M EDTA and 0.01 M NaOH reapectively (Ibitoye, 2008; Juo, 1979).

Determination of heavy metals in Soil, *Talinum triangulare* and *Celosia argentea* leaves

Available heavy metals (Cd, Ni and Pb) in soils were extracted with diethylene triamine penta acetic acid-triethanol amine (DTPA-TEA) extractant (Behera, 2022). While *T. triangulare* and *C. argentea* leaf were subjected to di-acid (HNO_3 + $HClO_4$ at 9:4)

digestion (Udo *et al*., 2009). Cd, Ni and Pb in the soil extract, *T. triangulare* and *C. argentea* leaf digest were measured and quantified using the atomic absorption spectrophotometer (Buck Scientific Model: VGP 210). The values obtain were compared with critical values reported by Allaway (1968), to determine permissible and toxicity levels in soils and vegetable (*T. occidentalis* and *C. argentea*) leaves.

Relationship between heavy metals contents in soils and Vegetable (*T. occidentalis* and *C. argentea*) Leaves

The relationship between the heavy metal content evaluated in soils and that in *T. occidentalis, C. argentea* leaves was determined by simple linear correlation.

Statistical analysis

Data obtained from soil, *T. occidentalis and C. argentea* leaves analysis were statistically analyzed using the Genstat statistical package (12th edition), while Duncan multiple range tests was used to separate means at $P \leq 0.05$.

Results and Discussion

Some physical and chemical properties of soils around Temboga riverbank

Results of some physical and chemical properties of the soils studied are shown in Table 1.

The textural classifications of the soils across the three distances Riverbank (RB), 60 meter from River bank (60 MRB) and 120 meters from River bank (120 MRB) were loamy sand as sand was the dominant soil fraction and had same value of 834.00 g kg^{-1} for RB, 60 MRB and 120 MRB. High value of sand content at the RB observed in this study aligns with the findings of Nwosu (2018), and could be due to sediment deposition by flowing water which carries and deposit soil particles around the RB. Silt content increased slightly while clay was slightly inconsistent amongst the distances away from Riverbank. The soil pH (H_2O) varied significantly with distances from Riverbank and with values of 5.55 (moderately), 5.99 (slightly) and 6.5 (slightly) acidic for RB, 60 MRB and 120 MRB respectively. The moderately and slightly acidic pH range obtained for soils around Temboga Riverbank aligns with the findings of Belay *et al.* (2023), who reported variation in soil pH with distances from Riverbank. Soil organic carbon ranges between 2.75% (120 MRB) and 3.42% (RB) could be said to be very high when compared to greater than 2% reported by Chude *et al.* (2011). Higher organic content of 3.42% and 3.34% obtained at RB and 60 MRB could be due to deposit of organic materials from the river and the use of organic manure by farmers raising vegetables around the RB soils, as observed in this study (Yusof *et al.,* 2009).

Heavy Metals Content in Soils around Temboga Riverbank

Heavy metal content of the soil studied is shown in Table 2. The soil heavy metals (Cd, Ni and Pb) levels at RB, 60 MRB and 120 MRM varied with distances away from the Riverbank but were not significantly different from each another. The Cd, Ni and Pd contents could be said to be within permissible and very low levels for Ni, compared to critical value of 0.01-0.70 mg Cd kg^{-1}, 10-100 mg Ni kg^{-1} and 2-200 mg Pd kg^{-1} respectively reported by Allaway (1968). Low levels Cd, Ni and Pb contents in soils around Temboga Riverbank have been earlier reported (Orhue *et al.,* 2025).

Heavy metal content of *T. triangulare* and *C. argentea* Leaf grown around Temboga Riverbank

The result of heavy metal (Cd, Ni and Pb) content of *T. triangulare* and *C. argentea* leaves is presented in Table 3 and 4.

The Cd, Ni and Pb levels varied in *T. triangulare* and *C. argentea* leaves grown around the river bank. The Cd content of *T.*

triangulare leaf (0.93 mg/kg) at 60 MRB was observed to have reached toxic levels, while the Cd content of *T. triangulare* leaces at RB and 120MRB could be said to have reached upper limit of critical level (Table 3), while Cd content of *C. argentea* leaves could be said to be within tolerance levels (Table 4), when compared with critical values of 0.2 – 0.8 mg/kg Cd reported by Allaway (1968). The low Cd content of *C. argentea* leaves could be due to selective absorption by the growing *C. argentea*. However, the low Cd content levels found in *C. argentea* grown around RB is in line with the findings of Kihampa and Nwegoha (2011), who reported low Cd content in vegetables grown around Riverbanks. The Ni content of *T. triangulare* leaves grown around the riverbank decreases significantly with increasing distance from the Riverbank while the Ni content of *C. argentea* leaves had the same value at RB and 60

MRB but decreased slightly at 120 MRB. The *T. triangulare* and *C. argentea* leaf grown at the RB and surrounding soils could be said to have reached toxic levels when compared with critical values of 1.00 mg kg^{-1} Ni reported by Allaway (1968). The toxic levels of Ni in the *T. triangulare* and *C. argentea* leaves could be due to excessive absorption from the soils. Toxic levels of Ni in *Telfaria occidentalis* leaves grown around the study area have been reported (Orhue *et al*., 2025). The Pb content of *T. triangulare* and *C. argentea* leaves grown at RB, 60 MRB and 120 MRB were not significantly different between distances from the river bank, however values obtained for Pb in *T. triangulare* and *C. argentea* leaves, were within tolerance level when compared with critical values of 0.1-10 mg kg^{-1} Pb (Allaway, 1968). The result aligns with findings of Orhue *et al*. (2025), who reported low levels of Pb in *Telfaria. Occidentalis* leaf grown around a Riverbank and dumpsite. The high content of Ni in *T. Occidentalis* and *C. argentea* leaves is an indication of higher tendency of *T. triangulare* and *C. argentea* to accumulate heavy metals (Ni), when grown around soils containing heavy metals, while the variation in heavy metal content amongst the distances from RB, could be due to the level of toxic substance reaching the soils from the flowing river water (Mansor *et al*., 2024; Hoque *et al*., 2023).

Relationship between heavy metals content in soil, *T.triangulare* and *C. argentea* leaves

The result show that heavy metals in soils, *T. triangulare* and ***C.*** *argentea* leaves were both positively and negatively correlated (related) but statistical significance were not detected (Table 5 and 6). Similar trend in relationship was observed for both *T. Triangulare* and *C. argentea* leaves, the findings was contrary to results of Emurotu and Onaiwu (2017) and Orhue *et al*. (2025), who have reported significant relationships between soils and vegetable grown around riverbanks.

Conclusion

The study found that although soil levels of Cd, Ni, and Pb along the riverbank were generally within safe limits for crop production, heavy metal concentrations in *T. triangulare* and *C. argentea* leaves varied significantly with distance from the riverbank. Cd content (0.93 mg kg^{-1}) in *T. triangulare* reached toxic levels at 60 MRB and was already at (0.77 mg/kg) upper tolerance limit at the riverbank and 120 MRB, suggesting a risk of toxicity over time. Both vegetables contained toxic levels of Ni, making them unsafe for regular human consumption, likely due to uptake from contaminated soils. Correlations between soil and plant heavy metal levels indicate that soil contamination influences plant absorption, even though the relationships were not statistically significant. The study recommends regular monitoring of riverbank soils and nearby areas to prevent heavy metal accumulation that could threaten human health and the environment.

Table 1: Some physical and chemical properties of the soils

Location	Sand	Silt	Clay	Text	pH	pH	OC	TON	Ca+Mg	EA
	——— % ———				(H_2O)	($CaCl_2$)	%		cmol/kg	
RB	83.40a	5.78a	10.82a	LS	5.55c	5.01c	3.42a	0.17a	0.10b	0.37a
60MRB	83.40a	6.34a	10.26a	LS	5.99b	5.41b	3.34a	0.17a	0.26a	0.29a
120MRB	83.40a	6.76a	9.84a	LS	6.51a	5.92a	2.75a	014a	0.34a	0.40a
Cv	2.00	16.80	12.40		3.10	2.00	29.4	29.40	33.30	40.70
SEM	0.95	0.61	0.74		0.11	0.06	0.54	0.03	0.04	0.08
SED	1.35	0.86	1.04		0.15	0.09	0.76	0.04	0.06	0.12

Text = texture, MRB = meters from Riverbank, OC = Organic carbon, TON = Total Organic Nitrogen, EA = Exchangeable Acidity, means with the same alphabets within columns are not significantly different at $p \leq 0.05$, using Duncan-multiple ranged test.

Table 2: Heavy metal contents of the soils around Temboga Riverbank in mg kg^{-1}

Location	Cd	Ni	Pb
RB	0.14a	0.06a	0.27a
60MRB	0.19a	0.07a	0.21a
120MRB	0.09a	0.07a	0.23a
cv	32.80	5.60	16.00
SEM	0.03	0.00	0.02
SED	0.04	0.00	0.03

Means with same alphabet within column are not significantly different from one another using Duncan multiple ranged tests at $P \leq 0.05$ significant level, in decending order. RB = Riverbank, MRB = meters from Riverbank.

Table 3: Heavy metal content of *T. triangulare* leaves in mg kg^{-1}

Location	Cd	Ni	Pb
RB	0.77a	4.42a	0.83a
60MRB	0.93b	2.32b	0.83a
120MRB	0.77b	2.22b	1.00a
cv	8.10	18.20	16.30
SEM	0.04	0.31	0.08
SED	0.05	0.44	0.12

Means with same alphabet within column are not significantly different from one another using Duncan multiple ranged test at $P \leq 0.05$ significant level, in descending order. RB = Riverbank, MRB = meters from Riverbank.

Table 4: Heavy metal contents of *C. argentea* leaves in mg kg^{-1}

Location	Cd	Ni	Pd
RB	0.167a	2.883a	1.167a
60MRB	0.27a	2.88a	1.17a
120MRB	0.17a	2.72a	1.30a
cv	24.80	8.70	14.60
SEM	0.17	0.14	0.10
SED	0.24	0.20	0.14

RB = Riverbank, MRB = meters from Riverbank, cv = coefficient of variation, SEM = standard error of means, SED = standard error of difference, LSD = leasr significant difference, means with the same alphabets within columns are not significantly different at $p \leq 0.05$, using Duncan multiple range test

Table 5: Relationship between heavy metals content in soil and *T. triangulare* leaf

Location	Cd	Pb	Ni
RB	0.000	-0.918	0.853
60 MRB	0.918	0.954	-0.945
120 MRB	-0.500	-0.721	-0.889

RB= River bank, 60MRB= 60 meters from Riverbank, 120MRB= 120 meters from Riverbank

Table 6: Relationship Between Heavy Metals in Soils and *C. argentea* leaf

Location	Cd	Pb	Ni
RB	0.9820	0.5000	0.9948
60 MRB	-0.528	0.1429	-0.500
120 MRB	-0.082	-0.7206	-0.9820

RB= River bank, 60MRB= 60 meters from Riverbank, 120MRB= 120 meters from Riverban

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