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Bioaccumulation of heavy metals in soils and *Telfairia occidentalis* leaf grown around a river bank and dump site

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ABSTRACT: River bank and dumpsites activities are threats to water and soil quality, as elevated heavy metal levels in soils around river banks and dumpsites may result in heavy metal entry into the food chain. This study aimed at accessing the concentration of heavy metals in soils and *Telfairia occidentalis* leaf grown around Temboga river bank and Oto-fure dumpsite, in Benin City, Nigeria. Surface (0-15 cm) soils and *T. occidentalis* leaf samples were collected at equidistance from Temboga river bank and Oto-fure dumpsite in 3 replicates. The soil samples were analyzed for some physical, chemical and heavy metal properties while *T. occidentalis* leaves were analyzed for Ni, Pb, Co, Cr, Se and Cd content in soil science analytical laboratory, University of Benin. Result showed that soil heavy metals content varied with distance from the river bank and dumpsite, Ni and Cr has reached toxic levels, while Pb, Cd, Se and Co accumulation are at potential toxic level in *T. occidentalis* leaf, with Ni content of 31.50, 13.00 and 12.50 mg kg^{-1}, Cr content of 8.92, 4.36 and 1.77 mg kg^{-1} at dumpsite, 60 m and 120 m away from dumpsite, respectively. It could be concluded that *T. occidentalis* leaf grown around the dumpsite was contaminated with Ni and Cr, while *T. occidentalis* leaf grown around river bank, contained elevated levels of Co, all these will pose health risk to food safety and humans consuming *T. occidentalis* leaves grown around the river bank and dumpsite studied.

Keywords: Buildup, contamination, fluted pumpkin, health risk, permissible levels, toxic

Heavy metal bioaccumulation is the process through which toxic metals and chemical compounds become bonded inside a cell structure (Nnabueze *et al.,* 2023). The accumulation can lead to significant toxic effects, posing health risks to the organism itself and other organisms higher in the food chain, through bio-magnification. Heavy metals have their way into the soil and water either through, natural process of rock weathering and or anthropogenic activities (Bhagwat, 2019; Edelstein and Ben-Hur, 2018; Islam *et al.,* 2019; Xia *et al.,* 2021). The use of fertilizers, pesticides, and irrigation with contaminated water can introduce heavy metals into agricultural soils (Amadi *et al.,* 2020). When injurious metals are introduced into soils at certain levels, it could affect soil chemical and biological (Friedlova, 2010; Wang *et al.,* 2024), and deteriorate soil fertility properties (Rahi *et al.,* 2022). Various metal transfer mechanism could lead to heavy metal uptake by crop plants (Skuza *et al.,* 2022). This can result in entry into the food chain and pose health risks to humans and animals (Amadi *et al.,* 2020). Due to nonbiodegradability, high toxicity and accumulation through food chain, heavy metal pollution can affect ecosystem functions, food security and human health risk (Acharya, 2024). Health risks, including kidney damage, neurological disorders, and cancers are often associated with consuming foods containing elevated levels of injurious metals (Akande *et al.,* 2021). While River banks are lands that flank a river and serves as boundary between flowing water and terrestrial environment, a dumpsite is an area of land used to dispose, store and manage waste. These land uses can results in certain environmental and human hazards (Ayoola, 2021). Some farmers now grow crops like *Telfairia occidentalis* in soils around river banks and dumpsites without knowledge of the heavy metals content in the soils and crops grown. Although several studies have been conducted on heavy metals status of crops grown along river banks (Adefarati *et al.,* 2024: Toheeb *et al.,* 2024) and dumpsites (Lissy and Madhu, 2020) soils and their effects on humans and animals health, but only little studies have examine heavy metal status in soils and *T. occidentalis* leaves around river banks and dumpsites in Benin metropolis. Hence, this study aimed at evaluating heavy metal (Ni, Pb, Co, Cr, Se and Cd) levels in soils and *T. occidentalis* leaf grown around a Temboga river bank and Oto-fure dumpsite in Benin City, Nigeria.

MATERIALS AND METHODS

The current study was carried out in areas where vegetables are cultivated for commercial purpose in Benin metropolis, Edo state, Nigeria, to evaluate heavy metal content of soils and *Telfairia occidentalis* (Fluted pumpkin) leaf grown around Temboga river bank and Oto-fure dumpsite. Temboga river bank site lies between latitude 6°21’28"N and longitude 5°38’56"E, sloppy and swampy closest to the river and planted to various vegetables, including *T. occidentalis*, *Amaranthus hybridus* (green leaf) and *Ocimum gratissimum* (scent leaf), the area is also used for fish farming activities. The soil in the area has a history of being treated with fertilizers (organic, inorganic) and herbicides. Oto-fure dumpsite, lies between latitude 6°27’49"N and longitude 5°36’03"E. N, the area is sloppy towards the dumpsite and crops grown include *Telfairia occidentalis*, *Capsicum annuum* and *Manihot* species. The study area is characterized by tropical climate with mean annual rainfall, temperature and relative humidity of 1900 mm, 23-37°C and 89-75% respectively (NIFOR, 2018). The soils are developed from coastal plain sand parent material, with intense weathering resulting from high precipitation and temperature (Okunsebor *et al.*, 2024). Auger surface (0-15 cm) soil and *T. occidentalis* leaf samples were collected from Temboga river bank, Oto-fure dumpsite, 60 and 120 meters away from the river bank and dumpsite in 3 replicate, for laboratory analysis in the month of October 2024. Collected soil samples were air-dried, ground with wooden mortal and sieved through a 2 mm sieve, *T. occidentalis* leaf were harvested, prepared, grind in a ceramic mortal and passed via a 0.5 mm sieve. The samples (soil and *T. occidentalis leaf*), were stored in a paper bag and analyzed for physical and chemical properties in the laboratory. The soil was fractionated 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), available P was extracted with Bray-1 solution according to methods of Bray and Kurtz (1945), while P in the extract was developed by colorimetric method (Murphy and Riley, 1962), and measured in a spectrophotometer (Buck Scientific Model: VGP 210) at 880 nm, exchangeable bases (Ca, Mg, Na, K) were extracted with 1 N NH_4OAc, buffered at pH 7, cation exchange capacity (CEC) was calculated by the method described by Udo *et al.* (2009). Exchangeable acidity (EA) was extracted and determined by 1 M KCl and titration method respectively (Juo, 1979). Effective cation exchange capacity (ECEC) was calculated by summation of CEC and EA, while Percentage base saturation was determined by the equation given below:

$$\% \text{ Base Saturation} = \frac{CEC}{ECEC} \times 100 \ldots\ldots\ldots\ldots (1)$$

Determination of available heavy metals

Heavy metals in Soil

Available heavy metals lead (Pb), selenium (Se), cobalt (Co), chromium (Cr), nickel (Ni), and cadmium (Cd) in soils were extracted with the diethylene triamine penta acetic acid-triethanol amine (DTPA-TEA) extractant, prepared according to the procedures described by Behera (2022) and measured using atomic absorption spectrophotometer (Buck Scientific Model: VGP 210).

***Heavy metals in Telfairia occidentalis* leaf**

Heavy metals in *T. occidentalis* leaf was determined by di-acid (HNO_3 + $HClO_4$ at 9:4) digestion method and the digest was analyzed for available Ni, Pb, Co, Cr, Se and Cd using Atomic absorption spectrophotometer (Buck Scientific Model: VGP 210).

Statistical analysis

The relationship between the heavy metal content evaluated in soils and *Telfairia occidentalis* leaves was determined by simple linear correlation. Data obtained from soil and *T. occidentalis* leaf 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

Particle size distribution

Table 1 shows some physical and chemical properties of the soils studied.

Particle size distribution express the percentage sand, silt and clay fractions of a soil, soils of the experimental area have been reported to be sandy (Orhue *et al.*, 2024). Sand was the dominant soil fraction which decreased with increased distance from the river bank and dump site. Sand content in river bank soil had values of 79.13, 77.13 and 77.08% at river bank (RB), 60 meters from river bank (60 MFRB) and 120 meters from river bank (120 MFRB) respectively, while sand content had values of 78.70, 78.30 and 77.20% at dumpsite, 60 meters from dumpsite (60 MFDS) and 120 meters from dumpsite (120 MFDS), respectively. Silt content was generally low at river bank and dump site soils, silt increased slightly away from the river bank and decreased slightly away from the dumpsite, clay content at river bank and dumpsite soils were slightly lower compare with distances away with values of 13.20 and 15.92% for river bank and dumpsite respectively, while the textural classification of the soil across both location were observed to be sandy loam. The highest value of sand content observed at the river bank could is due to sediment deposition by flowing water (Rodríguez-Rastrero *et al.*, 2023) which carries sand particles and deposits toward the river bank and dumpsite (Gupta *et al.*, 2023; Debnath *et al.*, 2023). The higher sand content in river bank and dumpsite soils as compared to soil away, found in this study is in line with the findings of Nwosu *et al.* (2018).

Some chemical properties of the soils

In the river bank soils, pH (1:2 in H_2O), of 4.73 was obtained from the river bank, while values of 5.73 and 5.40 was obtained for 60 meters away from river bank (60 MFRB) and 120 meters away from river bank (120 MFRB), while in the dumpsite soils, pH values of 5.90, 4.86 and 4.55 was obtained from dumpsite, 60 MFDS and 120 MFDS. The result indicates that the soils were acidic, while acidity decreases with increased distance away from the river bank, acidity increase with increased distance from the dumpsite, with no significance differences. Organic carbon content ranged from 1.08% at 120 MFRB to 1.85 % at river bank soil. However, or-

Table 1: Some physical and chemical properties of the soils

Location	Sand	Silt %	Clay	Txt	pH H_2O	OC %	Av. P mg/kg	CEC	EA cmol/kg	ECEC	BS %
					RIVER BANK SOILS						
River bank	79.13^a	7.67^a	13.20^a	SL	4.73^a	1.85^a	62.92^a	2.62^a	0.83^a	3.45^b	77.15^a
60 MFRB	77.13^a	8.67^a	14.20^a	SL	5.73^a	1.27^{ab}	32.83^b	1.75^b	0.99^a	2.70^b	67.80^b
120 MFRB	77.08^a	8.22^a	14.59^a	SL	5.41^a	1.08^b	13.02c	1.28^b	3.76^b	5.04^a	27.56c
SEM	3.22	1.61	1.72		0.16	0.16	36.90	0.24	0.77	0.87	8.80
SED	4.55	2.27	2.44		0.22	0.22	53.30	0.34	1.08	1.23	12.44
					DUMPSITE SOILS						
Dumpsite	78.70^a	5.41^a	15.92^b	SL	5.90^a	12.10^{ab}	16.70c	1.90^b	1.23^a	3.14^a	60.51^a
60 MFDS	78.30^a	4.75^a	16.92^{ab}	SL	4.86^a	13.23^a	49.00^b	1.08^a	1.00^a	2.08^a	51.92^b
120 MFDS	77.20^a	4.84^a	17.92^a	SL	4.55^a	11.24^b	54.70^a	1.01^a	0.57^b	1.58^b	63.92^a
SEM	1.93	0.69	1.72		0.39	1.31	11.35	0.38	0.34	0.58	8.82
SED	2.73	0.98	2.43		0.56	1.85	16.04	0.54	0.48	0.82	12.47

MFRB = meters from river bank, MFDS = meters from the dumpsite, Txt = texture, OC = organic carbon, Av. P = available phosphorus, CEC = cation exchange capacity, EA = exchangeable acidity, ECEC = effective cation exchange capacity, BS = base saturation, SL = sandy loam, SEM = standard error of means, SED = standard errors of differences of means, means with same alphabet within column are not significantly different at $p \leq 0.05$ using Duncan's multiple ranged test ganic carbon content of 1.27 % was obtained at 60 MFRB, while in the dumpsite soils, organic carbon content ranged from 11.24 % at 120 MFDS to 13.23 % at 60 MFDS. The high organic carbon content around the river bank and dumpsite obtained in this study is in line with the study of Okebalama *et al.* (2017). The high organic carbon obtained at 60 MFRB, could be due to the deposit of organic materials from the river and use of organic manure by farmers raising vegetables and fishes around the river bank (Shao *et al.,* 2024), while higher organic carbon around the dumpsite, could have likely resulted from dumping of organic waste in the dumpsite in line with the findings of Zahra *et al.* (2024) who reported high organic carbon content in dumpsite, resulting from unsystematic solid waste dumping. Available Phosphorus (Av. P) content of 62.92, 32.83 and 13.02 mg kg^{-1} was obtained in soils of river bank, 60 MFRB and 120 MFRB, while values of 16.70, 49.00 and 54.70 mg kg^{-1} were obtained in soils of dumpsite, 60 MFDS and 120 MFDS, respectively. The high values of Av. P obtained in and around the river bank and dumpsite imply P sufficiency when compared to the critical level of 10-16 mg kg^{-1} recommended by Adeoye and Agboola (1985). The high Av. P content in the river bank and soils around the river bank could be as a result of excessive use of P fertilizers by farmers around the study area in line with the findings of Mohammed *et al.* (2021), while high Av. P content around the dumpsite could be due to P mineralization from disposed waste, in line with the report of Okafor and Obaze (2024), who concluded that waste disposal sites have positive effects on soil fertility. High Av. P could also be due to the higher percent organic carbon content obtained in both river bank and dumpsite location, as organic matter have been reported to supply 75% of organic Phosphorus, in line with the studies of Orhue *et al.* (2024). The cation exchange capacity (CEC) and percentage base saturation (% BS) was observed to be the highest at the river bank while exchangeable acidity (EA) and effective cation exchange capacity (ECEC) were highest at 120 MFRB. The CEC and % BS had highest values of 2.62 cmolkg^{-1} and 77.15% at the river bank soil respectively, which implies higher capacity of the river bank soils to hold and exchange basic cations. However, the CEC values of 1.72 Cmol kg^{-1} and 1.28 Cmol kg^{-1} obtained for 60 MFRB and 120 MFRB soils respectively were in line with CEC results reported by Orhue *et al.* (2024). The ECEC values obtained from the river bank, dumpsite and their surrounding soils could be due to high levels of exchangeable acidity obtained in the soils as reflected in the results of the study. However, the values of ECEC obtained in the study were below 15 cmol kg^{-1} critical values reported by Udo *et al.* (2009) for tropical soils. The CEC, ECEC and base saturation status of a soil gives an insight on the fertility status (Onwuka and Ani, 2023). Orhue *et al.* (2024) have also reported that ECEC, could be used to evaluate the fertility status of a given soil.

Heavy metals content in soils around river bank and dump site

The heavy metal content in soils of river bank and dump site and are shown in Table 2.

The result showed that heavy metal (Ni, Pb, Co, Cr, Se and Cd) levels varied with distances away from river bank and dumpsite. In river bank soils, Ni levels were below the critical level of 10-1000 mgkg^{-1} reported by Allaway (1968). However, values of 1.36, 0.22 and 1.37 mg Ni kg^{-1} was obtained from river bank, 60 meters from river bank (60 MFRB) and 120 meters from river bank (120 MFRB), while values of 3.13, 1.28 and 1.61 mg Ni kg^{-1} were obtained at dumpsite, 60 meters from dumpsite (60 MFDS) and 120 meters from dumpsite (120 MFDS) respectively. This result indicated Ni contamination but below toxicity level around the river bank and dumpsite. The low Ni content obtained could be due to Ni absorption by crops grown in the area, contrary to the findings of Fayad *et al.* (2013) who reported higher level of Ni in river bank soils. The higher level of Ni reported by Fayad and his colleagues could be due to deterioration of the river bank over the years due to poor farming practices and industrial pollution. The Pb and Se content were higher at the river bank and dumpsite soils compared to the surrounding soils, the Pb and Se had values of 0.03, 0.02, 0.01 mg Pb kg^{-1} and 0.06, 0.02, 0.01 mg Se kg^{-} for river bank, 60 MFRB and 120 MFRB, while values of 0.03, 0.02 and 0.02 mg Pb kg^{-1} and 0.07, 0.05

and 0.03 mg Se kg^{-1} were obtained for dumpsite, 60 MFDS and 120 MFDS respectively. Although, these values of Pb and Se were below critical values (2-200 mg Pb kg^{-1} and 0.01-2 mg Se kg^{-1}) reported by Allaway (1968) and Dhillion and Dhillion (2009). The higher values obtained at the river bank and dumpsite soils implies that the Pb and Se contamination could be due to enrichment of the surrounding soils by the river water and waste pile respectively. Se levels in the river bank, dumpsite and surrounding soils is tending towards the 2 mg Se kg^{-1} upper limit and could reach toxic level in a short time. The higher Pb and Se content around the river bank found in this study align with the findings of Fayad *et al.* (2013) who reported higher heavy metal content around a river bank. Co and Cd content varied with distances from river bank and dumpsite, but were below critical values (1-40 mg kg^{-1} for Co and 0.01-0.7 mg kg^{-1} for Cd) reported by Allaway (1968). These values of Co and Cd content obtained could be due to anthropogenic activities around the river bank and dumpsite. This result of decreased Co content with increase distance away from the river bank found in this study is in line with the finding of Ayeni *et al.* (2010). The Cr content decreased with increased distance from the river bank and dumpsite, but the soils could be said to be low in Cr when compared with the critical range of 5-3000 mg Cr kg^{-1} (Allaway, 1968). The result of this study align with the findings of Nnamonu *et al.* (2015) also reported similar

Table 2: Heavy metals content in River bank and Dumpsite soils in mg/kg

Location	Ni	Pb	Co	Cr	Se	Cd
			RIVER BANK SOIL			
River bank	1.36^{a}	0.03^{a}	0.16^{a}	0.46^{a}	0.06^{a}	0.01^{a}
60 MFRB	0.22^{b}	0.02^{a}	0.16^{a}	0.21^{b}	0.02^{b}	0.01^{a}
120 MFRB	1.37^{a}	0.01^{a}	0.05^{b}	0.22^{b}	0.01^{b}	0.01^{a}
SEM	0.41	0.01	0.07	0.14	0.00	0.01
SED	0.58	0.01	0.09	0.19	0.01	0.01
			DUMPSITE SOILS			
Dumpsite	3.13^{a}	0.03^{a}	0.03^{b}	1.02^{a}	0.07^{a}	0.01^{a}
60 MFDS	1.28^{b}	0.02^{a}	0.11^{a}	0.36^{b}	0.05^{b}	^{B}DL
120 MFDS	1.61^{b}	0.02^{a}	0.06^{b}	0.08^{b}	0.03c	0.00^{a}
SEM	1.26	0.01	0.04	0.27	0.02	0.01
SED	1.78	0.01	0.06	0.38	0.02	0.01

MFRB = meters from river bank, MFDS = meters from dumpsite, BDL= below detectable limit, SEM = standard error of means, SED = standard, errors of differences of means, means with same alphabet within column are not significantly different at $p \leq 0.05$ using Duncan's multiple range test

Table 3: Heavy metals content in *Telfairia occidentalis* leaf in mg/kg

Location	Ni	Pb	Co	Cr	Se	Cd
			RIVER BANK SOILS			
River bank	2.56^{a}	0.19^{b}	0.46^{b}	0.13^{c}	0.31^{a}	BDL
60 MFRB	0.67^{b}	0.39^{a}	0.69^{b}	0.76^{a}	0.16^{b}	0.03^{a}
120 MFRB	1.29^{c}	0.03^{c}	1.51^{a}	0.22^{b}	0.24^{a}	0.02^{a}
SEM	0.81	0.14	0.66	0.37	0.05	0.012
SED	1.14	0.19	0.93	0.52	0.08	0.02
			DUMPSITE SOILS			
Dumpsite	31.50^{a}	0.27^{c}	1.21^{a}	8.92^{a}	1.46^{a}	BDL
60 MFDS	13.00^{b}	0.46^{a}	1.59^{a}	4.36^{ab}	1.42^{b}	BDL
120 MFDS	12.50^{b}	0.40^{a}	1.16^{a}	1.77^{a}	0.67^{b}	BDL
SEM	13.02	0.16	0.29	1.45	0.14	-
SED	18.41	0.23	0.41	2.04	0.20	-

MFRB = meters away from the dumpsite, MFDS = meters from dump site, BDL= below detectable limit, SEM = standard error of means, SED = standard errors of differences of differences of means, means with same alphabet within columns are not significantly different at $p \leq 0.05$ using Duncan's multiple range test

Table 4: Relationship between heavy metal in soil and *T. occidentalis* leaf

Location	Ni	Pb	Co	Cr	Se	Cd
			RIVER BANK SOILS			
River bank	0.999*	0.878	0.999*	0.955*	-0.711	-
50 MFRB	0.999*	-0.947	0.668	0.176	0.204	-0.982
100 MFRB	0.049	0.974	-0.634*	0.999*	-0.577	1.000***
			DUMPSITE SOILS			
Dumpsite	0.99*	0.04	0.76	0.99*	0.76	0.00
60 MFDS	0.98	0.87	0.62	0.90	-0.61	0.00
120 MFDS	0.99	-0.27	0.72	-0.12	-0.53	0.00

MFRB = meters from river bank, MFDS = meters from the dumpsite, * = significant at $p \leq 0.05$, *** = significant at $p \leq 0.001$

trend of Cr concentration in soils around river bank than soil away from river bank.

Heavy metals in fluted pumpkin (*Telfairia occidentalis*) leaf cultivated around river bank and dumpsites

The result of heavy metal content in fluted pumkin (*Telfairia occidentalis*) leaf is presented in Table 3. The result shown that Ni, and Se content of *T. occidentalis* leaf grown around the river bank and dumpsite, decreased with increased distance from the river bank and dumpsite, while Cd was below 0.2–0.8 mg kg^{-1} (detectable limit) in *T. occidentalis* leaf grown around at river bank and all dumpsite locations. Low Cd content (0.05 mg Cd kg^{-1}) in vegetables grown around river bank soil with some below detectable limit (BDL) has been reported (Kihampa and Mwegoha, 2010). Pb, Co and Cr content in *T. occidentalis* leaf were inconsistent with distances away from river bank and dumpsite; however Cr decreased with increased distance from the dumpsite. *T. occidentalis* leaf grown at river bank, 120 MFRB and all locations around the dumpsite contains excessive content of Ni as against the 1.0 mg Ni kg^{-1} permissible limit reported by Allaway (1968), while Ni buildup was observed in *T. occidentalis* grown at 60 MFRB, these excessive levels of Ni in the *T. occidentalis* leaf may pose health risk to consumers who regularly consume the *T. occidentalis* leaf grown around the river bank and dumpsite. *T. occidentalis* leaf grown around the river bank and dumpsite, were found to contain toxic levels of Co above permissible level of 0.05-0.5 mg Co kg^{-1} reported by Allaway (1968) which could result in Co toxicity, and can pose health risk to food chain and humans who regularly consume *T. occidentalis* grown around the river bank and dumpsite. The result also showed that Pb, Cr and Se were building up in *T. occidentalis* leaf grown around the river bank, while *T. occidentalis* leaf grown around dumpsite contains toxic levels of Cr, compared to permissible levels reported in literatures, the result corroborate the findings of Kihampa and Mwegoha (2010) who reported high Pb, Cr and Se content in vegetables grown around river banks. This result of toxic and buildup levels of heavy metals in the *T. occidentalis* leaf, found in this study could be due to bioavailability of from surrounding soils (Osemudiamen *et al.*, 2023; Oladeji and Saeed, 2015).

Relationship between heavy metals in soils and *Telfairia occidentalis* leaf

Table 4 shows the relationship between heavy metals in soils and *T. occidentalis* leaf.

The result showed that there were positive and negative relations between heavy metal content in soils and *T. occidentalis* leaf in the river bank and dumpsite soils. Significant correlation was observed for Ni at river bank (0.999 $p \leq 0.05$) and 60 MFRB (0.999 $p \leq 0.05$). Significant correlation was also observed for Co and Cr content at river bank (0.999 $p \leq 0.05$ and 0.955 $p \leq 0.05$) and 120 MFRB (-0.634 $p \leq 0.05$ and 0.999 $p \leq 0.05$) respectively, while Cd was highly significance at 120 MFRB (1.000 $p \leq 0.001$), however, significant positive relationship between soil and *T. occidentalis* leaf content was observed for Ni (0.990 $p \leq 0.05$) and Cr (0.990 $p \leq 0.05$) at dumpsite location. This implies that increase in heavy metal levels in soil will lead to significant increase in the amount of bioavailable heavy metals in *T. occidentalis* leaf except for Co at 120 MFRB where antagonistic relationship was obtained. Emurotu and Onianwa (2017) also reported significant relationship between heavy metals content in soils and *T. occidentalis*.

CONCLUSION

Soils along the river bank, dumpsite and adjacent areas contains potentially toxic levels of Se (0.06 mg kg^{-1} for riverbank, 0.07 mg kg^{-1} for dumpsite) and Cd (0.01 mg kg^{-1} for riverbank and dumpsite), although all the heavy metal studied were found to be highest at the river bank and dumpsite soil except Cd, suggesting that soil enrichment may be due to river overflow and waste pile in dumpsite, and could potentially reach toxic levels over time if not properly managed. Bioaccumulation of Ni (2.56 mg kg^{-1} for riverbank, 31.50 mg kg^{-1} for dumpsite) and Cr (0.13 mg kg^{-1} for riverbank, 8.92 mg kg^{-1} for dumpsite) in *T. occidentalis* leaf, has reached toxic levels, while Pb, Cd, Se and Co accumulation are at potential toxic level (building up) in *T. occidentalis* leafs grown around river bank and dumpsite with values approaching or exceeding the critical levels, which could be due to bioavailability of these heavy metals in surrounding soils. The findings suggests that the consumption of *T. occidentalis* leaves grown around Temboga river bank and Oto-fure dumpsites may pose risk to the food chain and human health, emphasizing the need for further research and mitigation strategies to reduce heavy metal enrichment in the soils.

The significant correlation observed between Ni (0.999 $p \leq 0.05$ for riverbank, 0.990 $p \leq 0.05$ for dumpsite), and Cr (0.995 $p \leq 0.05$ for riverbank, 0.990 $p \leq 0.05$ for dumpsite) concentration in soil and *T. occidentalis* leaf indicate that increased levels of these heavy metals in soil can lead to elevated accumulation in the crop. It is also recommended that cultivation and consumption of *T. occidentalis* leaf grown at the Oto-fure dumpsite and Temboga river bank, be discouraged as it has been found to contain toxic levels of Ni and Cr, with elevated levels Pb, Cd, Se and Co.

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