

Monitoring of Heavy Metals in Vegetables and Soils of Lokoja Riverside Soils, Kogi State, Nigeria

Mukhtar Mustapha (✉ almukh33@gmail.com)

Federal College of Education, Zaria, Nigeria

K. I. Omoniyi

Ahmadu Bello University

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Abstract

The purpose of these study was to assess the accumulation of heavy metals in riverside soils of river Niger and Benue and beyond the confluence and their uptake by *Amarantus hybridus* and *Corchorus olitorius* L grown on these soils. Four agricultural areas around the confluence point were selected. A total of 9 samples each of soils, were collected from the selected areas and were analyzed for pH, textural class, percentage organic carbon and matter, moisture content, Manganese, Nickel, Copper, Zinc, Lead and Cadmium. Soil pH ranged from 6.4 to 6.7, There was no significant difference in the mean values of the organic matter, organic carbon and moisture contents of the soils, while the total metal content ranges from 3.0–8.4 mg/kg for Cadmium; 10.2–20.2 mg/kg for Copper; 170.0–205.2 mg/kg for Manganese; 201.0–269.4 mg/kg for Nickel; 23.5–33.4 mg/kg for Lead and 48.7–77.8 mg/kg for Zinc. Nickel and chromium were in levels higher than the European Union Standards. The levels of Nickel, Zinc, lead and Cadmium in the vegetables were higher than the World Health Organisation permissible value in plants. The total metal contents in *A. hybridus* and *C. olitorius* L grown on the riverside soils follow the ranking: Ni > Mn > Zn > Pb > Cu > Cd. Of all the metals studied, Pb had the highest bioaccumulation factor, 0.5691 and 0.6301 in the soil from CN site for *A. hybridus* and *Corchorus olitorius* L respectively this indicated that the highly toxic metal lead has been entering our food chain through vegetables.

Background

Heavy metal contamination refers to the excessive deposition of toxic heavy metals in the soil caused by human activities. Heavy metals in the soil include some significant metals of biological toxicity, such as mercury, cadmium, lead, chromium and arsenic, etc. They also include other heavy metals of certain biological toxicity, such as zinc, copper, nickel, stannium, vanadium, and so on.

Irrigation on river side soils of River Niger and Benue help to provide vegetable crops for the people of Lokoja and the environs during the dry season and early part of the rainy season. Kogi State faced the problem of flooding in 2012, consequently, large items were washed into the water body, thus the level of heavy metals in both soils and plants grown on the river side soils are expected to be elevated beyond the threshold levels. It is worthy of note that these two rivers come from far distance, therefore, domestic industrial, mining, metallurgical and agricultural activities contributes to the heavy metal loading of the water and neighboured riverside soils being irrigated with the water from the rivers. These activities leads to heavy metal loading of the soil, therefore the determination of the heavy metal levels of the riverside soils post flooding becomes imperative.

Determination of the heavy metal uptake is further justified, since these metals are taken up by plants and from here enter into the food chain where they may cause health hazards. The pollution indices of the riverside soil will help to determine the level of pollution loading after the flooding of 2012 when data is compared to that in literature before the flood.

It is based on these facts that this study is aimed at determining the levels of some heavy metals in riverside soils of River Niger, River Benue and beyond the confluence point, and to assess the heavy metal uptake by some crops planted on the soils.

Methods

The river side soils for total metal determination were collected from the bank of River Niger and River Benue and beyond the confluence point at 0–15 cm and 15–30 cm depth. The collection site was 50 m away from the bank of the river and each point of collection was 10 m away from the other (n = 60).

Another set of soil samples (0–30 cm) were collected at the dry season 50 m from the river bank (n = 10) for pot culture experiment to determine the amounts of Cd, Cu, Mn, Ni, Pd and Zn absorbed by *Amarantus hybridus* and *Corchorus olitorius* L.

Soil sample for control experiment were collected from a farmland far away from the two rivers since this part is not affected by water from the river.

Pot Culture Experiment for the Plants

In order to study the phytoavailability of the Cd, Cu, Mn, Ni, Pd, Zn in the two plants, seeds of spinach (*Amarantus hybridus*) called “aleyafu” in Hausa, “Inine” or “Opotoko” in Igbo and “Efo” in Yoruba and jute (*Corchorus olitorius* L.) called “Laalo” or “Malafia” in Hausa, “Arira” or “Ahihara” in Igbo and “Oyoyo” or “Ewedu” in Yoruba, were planted separately on 5 kg of the soil in pots having no hole at the bottom (see Fig. 1 below). Three seedlings per pot after germination were plant cultured (watering twice a day, weeding manually, exposure to sunlight and with adequate plant protection measures). The pot culture experiment was carried out in a glass house at Crop Protection Department, Institute of Agricultural Research, Ahmadu Bello University, Zaria, Nigeria. They were uprooted after six (6) weeks. Identification of the plant was done at the Herbarium of the Department of Biological Sciences, Ahmadu Bello University, Zaria, Nigeria. This was carried out in the Month of August 2014. The *Amarantus hybridus* was identified with Herbarium number; V/no.: 2400 and *Corchorus olitorius* L. with Herbarium number; V/no.: 2649.

Pre – treatment of the soil and plant samples

Soil samples from each site were homogenized in an agate mortar and then air dried overnight in circulating air in an oven at 30°C. It was then allowed to pass through a 2 mm sieve. The sieved soils were placed in polythene bags and ready for analysis.

The Plant samples *Amarantus hybridus* and *Corchorus olitorius* L. were properly rinsed with tap water and then with distilled water to remove any attached soil particles, they were then cut into smaller portions and then placed in large clean crucible where they were oven dried at 100°C for 48 hours in order to remove moisture. The dried plant samples were grounded into fine particles using a clean acid-washed agate mortar and pestle.

The glasswares were washed with liquid soap, rinsed with distilled water and then soaked in 10% HNO_3 solution for 24 hours (Todorovi et al., 2001). The wares were then rinsed with plenty distilled water and later dried in a Memmert drying oven at 80°C for 5 hrs.

Digestion of Samples

Digestion of soil samples

The samples of soil were digested in order to carry out heavy metal analysis on them using the method of Ogunfowokan *et al.* (2009). 1.0 g sample of the soil sample was digested in a Teflon cups with 30 cm^3 aqua-regia ($\text{HCl}:\text{HNO}_3$, 3:1) on a thermostatted hotplate at 150°C . After, about 2 hour of digestion, the Teflon cup with its content was brought down from the hot-plate to simmer. Then, 5 cm^3 HF was added to the mixture and heated further for 30 min. The Teflon cup with its content was then allowed to cool to room temperature and filtered. After which the filtrate was quantitatively transferred into 50 cm^3 volumetric flask and made to mark with distilled water.

Digestion of plant samples

The plant samples harvested after six weeks from the pot experiment conducted in the procedure 3.4.2 were digested according to Awofolu (2005). A 0.5 g dried plant sample each of *Amarantus hybridus* and *Corchorus olitorius L* was weighed into 100 cm^3 beaker, a mixture of 5 ml concentrated HNO_3 and 2 ml HClO_4 was added and digested at low heat using a hot plate until the content was about 2 cm^3 . The digest was allowed to cool and then filtered into 50 cm^3 standard flask. The beaker was then rinsed with small portions of distilled-deionized water and then filtered into the flask.

Each digest was carried together with blank for triplicate determination of As, Cd, Cu, Mn, Pb and Zn contents using Atomic Absorption Spectrophotometer (AAS).

Results

Table 1

Physicochemical Parameters and Heavy Metal Contents of Riverside Soil of River Niger and Benue in wet season 2014

Soil property		N soil(mg/Kg)	B soil(mg/Kg)	CN soil(mg/Kg)	CB soil(mg/Kg)
pH		6.7	6.5	6.5	6.4
% sand		84	50	62	76
% clay		6	34	26	10
%silt		10	16	12	14
Textural Class		Loamy sand	Sandy clay loam	Sandy loam	Sandy loam
Organic Carbon (%)		0.249	0.958	0.563	0.822
Organic Matter (%)		0.533	1.859	1.311	1.034
Moisture Content		81.20 ± 0.01	73.50 ± 0.10	68.10 ± 0.12	73.75 ± 0.03
Total Cd (mg/kg)	15cm	7.3 ± 0.0009	8.4 ± 0.0003	7.6 ± 0.0003	8.4 ± 0.0005
	30cm	3.3 ± 0.0007	4.2 ± 0.0004	3.0 ± 0.0005	3.4 ± 0.0004
Total Cu (mg/kg)	15cm	11.60 ± 0.0004	20.20 ± 0.0005	18.30 ± 0.0003	18.00 ± 0.0005
	30cm	10.20 ± 0.0003	18.70 ± 0.0013	19.40 ± 0.0004	17.50 ± 0.0004
Total Mn (mg/kg)	15cm	179.30 ± 0.0036	205.20 ± 0.0041	195.20 ± 0.0032	171.00 ± 0.0028
	30cm	176.30 ± 0.0032	201.10 ± 0.0039	193.30 ± 0.0035	170.00 ± 0.0030
Total Ni (mg/kg)	15cm	269.40 ± 0.0004	267.40 ± 0.0005	201.00 ± 0.0004	220.80 ± 0.0005
	30cm	262.90 ± 0.0005	211.70 ± 0.0003	206.70 ± 0.0005	210.40 ± 0.0007
Total Pb (mg/kg)	15cm	23.5 ± 0.0002	33.4 ± 0.0003	24.6 ± 0.0006	28.1 ± 0.0002
	30cm	23.5 ± 0.0003	32.2 ± 0.0003	25.1 ± 0.0005	28.0 ± 0.0004
Total Zn (mg/kg)	15cm	63.10 ± 0.0025	77.80 ± 0.0012	50.00 ± 0.0014	51.60 ± 0.0026
	30cm	61.7 ± 0.0030	74.1 ± 0.0021	48.7 ± 0.0021	50.0 ± 0.0010
***N Niger riverside soil, B Benue Riverside soil, CN Niger riverside soil after confluence, CB Benue river side soil after confluence					

Table 2
Permissible limits of heavy metals in soils and plant.

Elements	*Threshold concentration of soil (mg/kg) (EU 2002)	#Permissible value of plants (mg/kg) (WHO 1996)
Ni(Nickel)	75	10
Cu(Copper)	140	10
Zn(Zinc)	300	20
Pb(Lead)	300	2
Cd(Cadmium)	3	0.2
Mn(Manganese)	2000	300

*The heavy metals concentrations of Cd, Cu, Mn, Ni, Pd and Zn In the soil samples collected from riverside soils of River Niger, Benue and Benue and after the confluence point (Table 1) would be compared with European Union Standards (EU, 2002).

#The heavy metals concentrations of Cd, Cu, Mn, Ni, Pd and Zn In the *Amarantus hybridus* and *Corchorus olitorius* L would be compared with World Health Organization permissible value in plants (WHO, 1996).

Level of Heavy Metal in *Amarantus hybridus* and *Corchorus olitorius* L

Heavy metal concentrations in spinach (*Amarantus hybridus*) called “aleyafu” in Hausa, “Inine” or “Opotoko” in Igbo and “Efo” in Yoruba and jute (*Corchorus olitorius* L.) called “Laalo” or “Malafia” in Hausa, “Arira” or “Ahihara” in Igbo and “Oyoyo” or “Ewedu” in Yoruba, were found to be generally lower than that levels of each of the heavy metals in the soil, as shown in Figs. 2a-f and for *Amarantus hybridus* and *Corchorus olitorius* .L.

Bioaccumulation factor (BF) of the Heavy Metals in *A. hybridus* and *Corchorus olitorius*

In order to determine the extent of contamination content of the heavy metals in soil, an enrichment factor was computed called the transfer factor of bioaccumulation factor (BF). This was expressed as the ratio of the concentration of the metals in the plants to that in the soil (Oyedele et al., 1995). Table 3a presents the BF for *Amarantus hybridus*, while Table 3b presents for *Corchorus olitorius* L. bioaccumulation factor (BF) varied significantly among the soil species of the heavy metals. Of all the metals studied, the BF of Pb from the soil to the plant was highest, being 0.5691 and 0.6301 considering the soil from CN to *A. hybridus* and *Corchorus olitorius* L, respectively.

Table 3a
Bioaccumulation Factor (BF) of the Heavy Metals
in *Amarantus hybridus*

Metal	N	B	CN	CB
Cd	0.1370	0.1667	0.1316	0.1667
Cu	0.3879	0.2970	0.2240	0.2389
Mn	0.2086	0.1598	0.1670	0.1789
Ni	0.1496	0.1410	0.1801	0.1268
Pb	0.5319	0.3952	0.5691	0.4982
Zn	0.2995	0.2236	0.3760	0.3663

Table 3b
Bioaccumulation Factor (BF) of Heavy Metals in
Corchorus olitorius L

Metal	N	B	CN	CB
Cd	0.1370	0.2024	0.1974	0.1190
Cu	0.3879	0.3069	0.2350	0.1778
Mn	0.2070	0.1842	0.1552	0.1895
Ni	0.1496	0.1410	0.1801	0.1268
Pb	0.5234	0.3712	0.6301	0.5587
Zn	0.2757	0.2082	0.3300	0.3178

Discussion

Physicochemical Parameters of the Farmland Soils near River Niger, Benue and Beyond Confluence point

Physicochemical properties as well as Heavy metal concentrations in the soil samples collected from the riverside soils are given in Table 1.

Soil pH ranged from 6.4 to 6.7 for the farmland soils of River Niger, Benue and beyond the confluence for the contaminated soils. These lower pH values may be attributed to acid effluent coming from nearby industrial operations as well as high organic content.

The Organic Matter content was low as a result of intensive use of these soils and the rapid mineralization of Organic Matter under semiarid conditions. The organic matter contents of the soil plays

an important role in absorption reaction in the soil, hence prevents pollutants from reaching ground water sources (Alloway *et. al*, 1995).

Heavy Metal Content in the Riverside Soil Samples Used for Agricultural Purposes

Cd concentrations of the studied area as shown in Table 1 indicated that Cd concentration of value 8.4 mg/kg obtained in both site B and CB was the highest concentration; while the Cd concentration (3.0 mg/kg) at CN sampling site was the lowest. The Cd concentrations obtained were higher than the European Union Standards of 3 mg/kg (EU, 2002) as seen in Table 2. Cadmium is regarded as one of the most toxic trace elements in the environment. Cadmium occurs naturally in soils as a result of the weathering of the parent rock (Alloway, 1995). Although most natural soils contain less than 1 mg kg^{-1} cadmium from the weathering of parent materials, those developed on black shales and those associated with mineralised deposits can have much higher levels (Alloway, 1995). Cadmium is higher in the studied area, this could be due to the use of phosphatic fertilizers, irrigation by untreated water of the river and due to the soil of the study area being from deposits of the flooding of year 2012; and the soil have been derived from sediments (sand, silt and clay) of the River Niger and Benue. Surface soils commonly contain higher concentrations of Cd than subsurface horizons. The higher concentrations of Cd in surface horizons are probably due to the cycling of Cd from lower depths to the surface by plants Page et al., (1987).

Copper content was reported to be lower than that of European Union Standard limit (EU 2002) of 140 mg/kg (Table 2). Copper had relatively low values ranging from 10.2 mgkg^{-1} in the soil at N to 20.2 mgkg^{-1} in B. The concentrations of copper are higher in some soil samples due to the irrigation of agricultural lands with untreated river water which could lead to the accumulation of Cu in soils. The Cu concentrations are lower due to the continuous removal of heavy metals by the food crops grown in this area and also due to leaching of heavy metals into the deeper layer of the soil and to the ground water.

As seen in Table 1, manganese concentration in the soil is generally higher than all the other metals recorded but it is generally lower than the European Union Standards of about 2000 mg/kg (EU, 2002). It ranges from 170.00 mg/kg to 205.20 mg/kg. The observed large concentration of Mn in the soil samples might have been due to background concentration of Mn in the soil and sediment of the river. Dara, (1993) reported that manganese may be found in most soil since it is one of the elements in the earth crust.

Ni concentrations in the soil samples of the study area are higher than that of European Union Standards (EU 2002) of 75 mg/kg. It ranges from 201.0 to 269.4 mg/kg. Nickel occurs naturally in soils as a result of the weathering of the parent rock (McGrath, 1995). The underlying geology and soil forming processes strongly influence the amount of nickel in soils with higher median concentrations reported in clays, silts, and fine grained loams relative to coarser grained loams, sandy and peaty soils (Mohamed, 2014). Agricultural fertilisers, especially phosphates, are also a significant source of nickel in soil but it is

unlikely to build-up in soil in the long term from their use (McGrath, 1995). The irrigation of the farmland in riverside of River Niger and Benue by the river water and use of agricultural fertilizers may account for the increase in the Ni concentrations of the farmland.

Lead contents were found to be highest (33.4 mgkg^{-1}) in the soil sample from B and lowest (23.5 mgkg^{-1}) at N sampling site. The value of Pb in the soil samples were generally low compared to the European Union Standards of about 300 mg/kg (EU 2002), Lead particles are deposited in the soil from flaking lead paint, from incinerators (and similar sources), and from motor vehicles that use leaded gasoline. Waste disposal is also a contributory factor to increased Pb in soil. Urban environments in general have received higher depositions of lead from vehicular emissions than rural areas have; though Pb in antiknock additives used in gasoline has been banned and not currently used in many countries. When lead is deposited in soil from anthropogenic sources, it does not biodegrade or decay and is not rapidly absorbed by plants, so it remains in the soil at elevated levels. Lead is toxic to humans, and poisoning can occur either through ingestion of lead or by breathing in lead dust. Both long-term low-dose and short-term high-dose exposure can permanently damage the nervous, renal (kidney), and hematopoietic (blood-forming) systems.

Zn contents as presented in Table 1, indicated that the soil samples in site CN (48.7 mgkg^{-1}) was the lowest while the sample from B (77.80 mgkg^{-1}) had the highest Zn concentration. The highest Zn concentrations of the studied area are lower than that of European Union Standards of 300 mg/kg (EU 2002). Zn is released to the environment from both natural and anthropogenic sources; however, releases from anthropogenic sources are greater than those from natural sources. The most important sources of anthropogenic zinc in soil come from discharges of smelter slags and wastes, mine tailings, coal and bottom fly ash, and the use of commercial products such as fertilizers and wood preservatives that contain zinc. Zinc does not volatilize from soil. Although zinc usually remains adsorbed to soil, although leaching has been reported. The lower concentrations of the Zn than the safe limits of EU at most sites might be due to the continuous removal of heavy metals by the food crops grown in this area and also due to leaching of heavy metals into the deeper layer of the soil and to the ground water.

Level of Heavy Metal in *Amarantus hybridus* and *Corchorus olitorius* L

Concentrations of cadmium (Fig. 2a) in *A. hybridus* was found to be lowest (1.0 mgkg^{-1}) in the plant from N and CN, and was highest (1.4 mgkg^{-1}) in the crop planted on B and CB soil samples. For *Corchorus olitorius* L., the lowest Cd level was 1.0 mgkg^{-1} in the plant from N and CB and the highest level was 1.7 mgkg^{-1} in the crop planted on site B soil sample. The plant in the control soil had relatively lower value both for *A. hybridus* and *Corchorus olitorius* L. compared to the experimental soils. There was significant difference in the values recorded in *A. hybridus* compared to *Corchorus olitorius* L.

Copper contents in *A. hybridus* as presented in Fig. 2b ranged from 4.1 in the crop harvested from CN to 6.0 mgkg^{-1} in the plant from site B; while in *Corchorus olitorius* L, it ranged from 3.2 in CB to 6.2 mgkg^{-1} in B. The extremely high value obtained in site B both in *A. hybridus* and *Corchorus olitorius* L, could be due

to the decomposition of solid wastes containing high copper contents, which are drain into the rivers and subsequently in the soil. In the control sites very low values were recorded in both the *A. hybridus* and *Corchorus olitorius* L. This could be due to the fact that the site is not affected by the untreated water of the river. These values are however above the tolerance limit (10 mgkg^{-1}) set by WHO, (1996) as seen in Table 2. There was no significant difference in the values recorded in *A. hybridus* compared to *Corchorus olitorius* L.

Manganese contents as presented in Fig. 2c, had the lowest value in *A. hybridus* planted on the soil of site CB (30.6 mgkg^{-1}) and was highest in the plant harvested from the soil of N (37.4 mgkg^{-1}). On the other hand, for *Corchorus olitorius* L. the lowest level of Mn was 30.3 mgkg^{-1} for the ones from CN soil and 37.8 mgkg^{-1} the highest Mn level recorded in the plant from B soil sample. From the Fig. 4.4c, it is indicated that the plant from the control site had relatively high level of Mn for both *A. hybridus* and *Corchorus olitorius* L, which is as expected. In addition, there was little significant difference in the values obtained for both *A. hybridus* and *Corchorus olitorius* L.

Nickel contents (Fig. 2d) was relatively higher than manganese, and was the highest level recorded among all the metals studied, the lowest value of Ni in *A. hybridus* was recorded in the ones planted on the soil from CN (36.7 mgkg^{-1}) and the highest Ni was recorded in the plant harvested from the soil of B (51.2 mgkg^{-1}). For *Corchorus olitorius* L. 28 mgkg^{-1} was the lowest level of Ni in the crop from site CB and 40.3 mgkg^{-1} was the highest Ni level recorded in the plant harvested from site N soil. Figure 4.4d indicated that the plant from the control site had relatively low level of Ni in both the *A. hybridus* and *Corchorus olitorius* L. In addition, there was no significant difference in the values obtained for both *A. hybridus* and *Corchorus olitorius* L.

Lead contents (Fig. 2e) measured was lowest in *A. hybridus* planted on the soil from N (12.5 mgkg^{-1}) and was highest in the plant from CB and CN soils (14 mgkg^{-1}). For *Corchorus olitorius* the lowest level of Pb was 12.3 mgkg^{-1} obtained in the plant from N soil. The highest amount of Pb was 15.7 mgkg^{-1} recorded in the plant from CB soil. The control plant had relatively lower value both for *A. hybridus* and *Corchorus olitorius* L compared to the experimental plants. There was no significant difference in the values recorded in *A. hybridus* compared to *Corchorus olitorius* L.

Zinc contents (Fig. 2f) in *A. hybridus* planted on the soil ranged from 17.4 in soil from B to 18.9 mgkg^{-1} in the soils from N and CB; for *Corchorus olitorius* L, Zn level ranged from 16.2 in the sample planted on B soil to 17.4 mgkg^{-1} in the one from N. The concentration of zinc in the control site was higher than those in the sample area, this could be attributed to the background zinc present in the soil (Dara, 1993). These zinc values recorded in the experimental plant are above the tolerance limit of zinc in plant and could be harmful to man if accumulated over time through the food chain. There was significant difference in the values recorded in *A. hybridus* compared to *Corchorus olitorius* L as seen in Appendix IV.

The ranking of these metals in *A. hybridus* and *Corchorus olitorius* L planted on the riverside soils is in the order: Ni > Mn > Zinc > Pb > Cu > Cd, while the pattern in the control site was Mn > Zn > Ni > Pb > Cu > Cd.

Bioaccumulation factor (BF) of the Heavy Metals in *A. hybridus* and *Corchorus olitorius*

The Bioaccumulation Factor obtained for Ni with *A. hybridus* and *Corchorus olitorius* L was the lowest with the exception of the values using soil from CN (0.1801). Similar trend was observed for Cd except in *Corchorus olitorius* L using soil from B (0.2024) where transfer factor was relatively high. These results indicate that *A. hybridus* and *Corchorus olitorius* L, have potential to accumulate more of Pb and Cu from the riverside soil compared to Ni and Cd. There is tendency of Pb and Cu in the soil of the farmland from River Niger and Benue in Lokoja to be transferred into the food chain through the consumption of edible plants on the site by either animals or man. Hence consumptions of these plants overtime may cause some health hazards as reported by Uba et al. (2008). It was also observed that the transfer factor or bioaccumulation factor values recorded for the metals show reverse trend compared to the total metal content obtained across the seasons $Pb > Cu > Zn > Mn > Cd > Ni$. According to Udosen et al. (2006) some factors such as pH, exchange binding capacities, climate change and morphology of the plant might have contributed to low transfer factor values obtained in the riverside soils to the plant.

CONCLUSIONS

From the present study it can be concluded that in some agricultural fields the concentration of, Ni and Cd are above the normal soil value and reflect the possibility of soil pollution. Accumulation of Nickel, Zinc, Lead and Cadmium in the vegetables in both leafy *A. hybridus* and *Corchorus olitorius* L. which are higher than the WHO permissible value of plants (1996), indicated that the highly toxic metal Pb has been entering our food chain through vegetables. Although the green vegetables are the good sources of Zn, Cu, Fe necessary for our good health, but by the accumulation of toxic metals like Ni, Pb and Cd, the essential micronutrients would be deficient in our daily diet. In heavy metal contaminated areas leafy vegetables which are good accumulator should be avoided for commercial farming and should be substituted by non-accumulator plant like potato.

Abbreviations

N = Niger Riverside Soil,

B = Benue Riverside Soil,

CR = Right side Soil after Confluence,

CL = Left side Soil after Confluence.

EU, 2002 = European Union Standard Limits, 2002

WHO, 1996 = World Health Organization Permissible Limit, 1996

Declarations

Ethics approval and consent to participate;

All ethics approval and consent to participate is here by allowed

Consent for publication;

I hereby give the consent for this manuscript to be published

Availability of data and materials;

All data and materials are readily available

Competing interests;

There is no any competing interest

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Authors' contributions;

I Mukhtar Mustapha carried out the research as requirement for award on MSc in Analytical Chemistry while K.I Omoniyi supervised the research

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Figures



Figure 1

Pot culture experiment for the plants

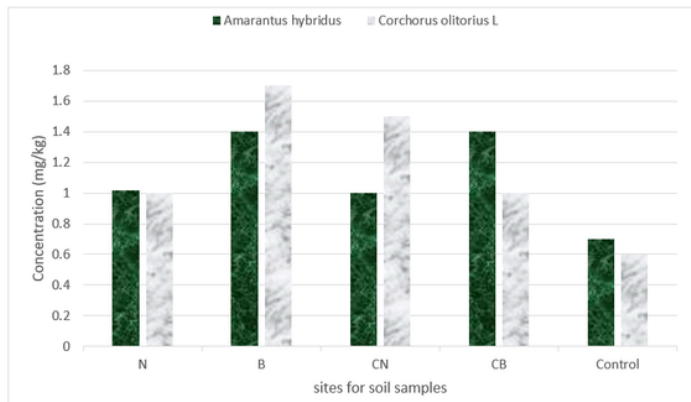


Figure 2a:

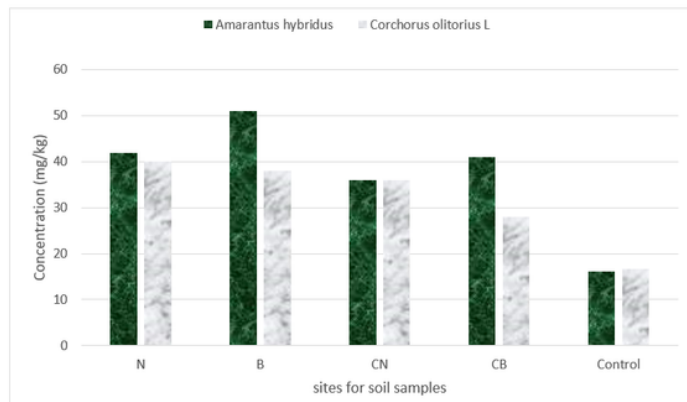


Figure 2d:

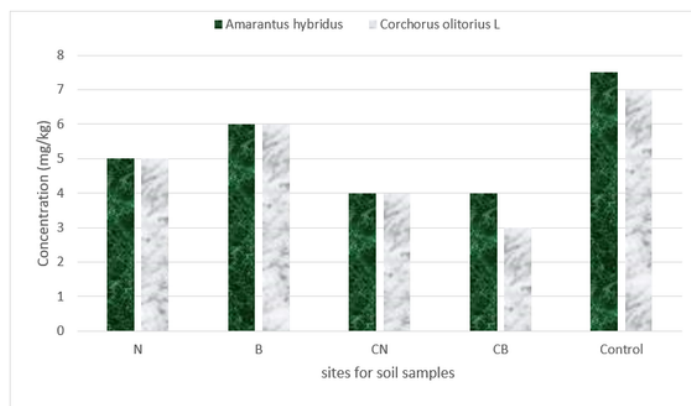


Figure 2b:

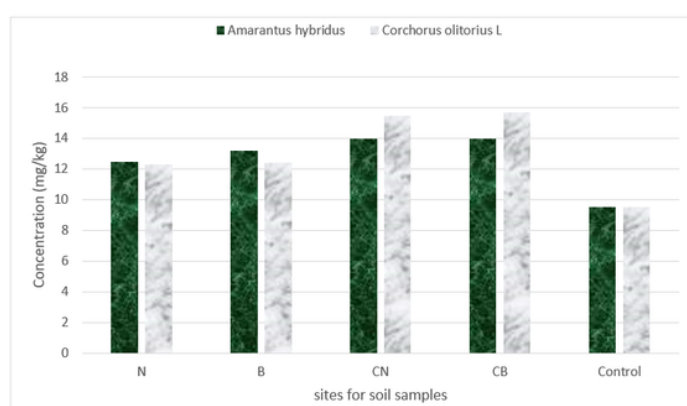


Figure 2e:

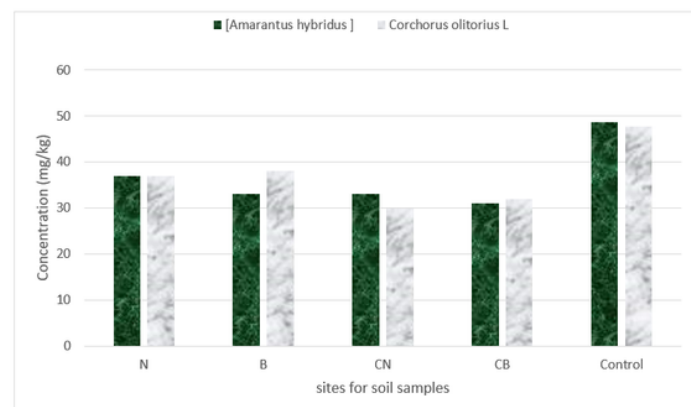


Figure 2c:

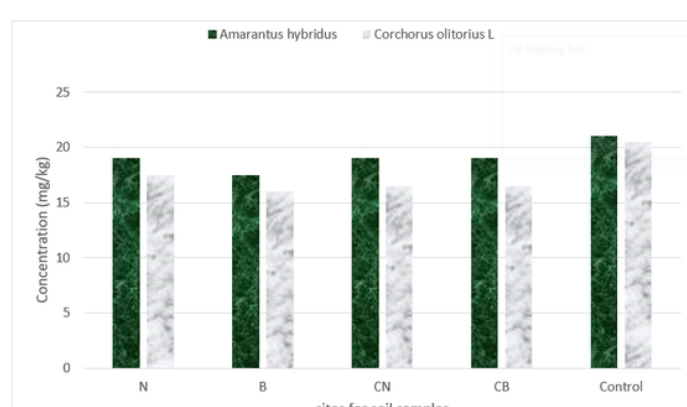


Figure 2f:

Figure 2

2a: Cadmium content in the two plants grown on riverside soils in the pot experiment

2b: Copper content in the two plants grown on riverside soils in the pot experiment

2c: Manganese content in the two plants grown on riverside soils in the pot experiment

2d: Nikel content in the two plants grown on riverside soils in the pot experiment

2e: Lead content in the two plants grown on riverside soils in the pot experiment

2f: Zinc content in the two plants grown on riverside soils in the pot experiment