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Assessment of the Level of Heavy Metals in Soil and Vegetables in Irrigation Farming Sites in New-Bussa and its Environment, Niger State, Nigeria

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Abstract
Heavy metal contamination of vegetables is a great public health concern. Hence this study investigates concentration of heavy metals in leafy vegetables and soil from irrigation farming sites in New-Bussa and its environment, Niger State Nigeria. Concentrations of the following heavy metals; Pb, Cr, Zn, Cu and Cd were determine in *Amaranthus cruentus*, *Corchorus aestuans* and soil from the study area. Freshly harvested *Amaranthus cruentus* and *Corchorus aestuans* were collected from three farmlands. Analysis for heavy metals was carried out using Atomic Absorption Spectrophotometer. The mean heavy metals concentrations in soil samples collected at different farmlands in the study area showed the presence of all heavy metals tested (Pb, Cr, Zn, Cu and Cd) at varying concentrations ($p<0.05$) across the sampling stations. Zn was highly concentrated at the three farmlands with highest concentration at farm B (7.90 ± 0.00 mg/kg^{-1}), followed by Cr which recorded the highest concentration at farmland C with a mean of 1.90±0.00 mg/kg^{-1}. Pb recorded the highest concentration at farmland B with a mean of 0.40±0.07 mg/kg^{-1}while the least concentration was recorded at farmland C with a mean of 0.10±0.00mg/kg^{-1}. Cd recorded the lowest heavy metal concentration among the metals tested with the least concentration at farmland C with a mean of 0.02±0.04mg·kg^{-1}. Average mean concentrations of 4.22 mg·kg^{-1}, 1.40 mg·kg^{-1}, 0.27 mg·kg^{-1}, 0.13 mg·kg^{-1} and 0.005 mg·kg^{-1} were recorded for Zn, Cr, Pb, Cu and Cd respectively in the soil.

Keywords: Farmlands; Heavy Metals; Irrigation; Soil; Vegetables

Introduction

Vegetables are of great benefits because they are good source of vitamins, minerals and plant proteins in human diet all over the world (Yalemtsehay and Fisseha, 2016). Vegetable cultivation is one of the most efficient and major branches of agriculture and of economic values in Nigeria. Several vegetables are cultivated for their nutritional and medicinal values. However, despite their economic importance, majority of these consumed veggies were on the list of underutilized plant species for Research in Nigeria (Leipzig, 1996).

Accordingly, the evaluation and control of food safety hazards is one of the key research priorities of scientists. The rapid and unorganized urbanization and industrialization have been accompanied by elevated amounts of heavy metals in foodstuff which will, in turn, pose a threat to human health (Ali and Al-Qahtani 2012). Because of being unbiodegradable, and having long biological half-lives and a high potential for accumulation in different body organs, heavy metals are regarded as the most dangerous pollutants (Radwan and Salama 2006). The food chain is the major pathway of human exposure to heavy metals (Khan *et al.,* 2013). Compared to the grain or fruit crops, leafy vegetables, as one of the most important staple foods in most household, have been shown to accumulate heavy metals at a greater capacity (Salehipour *et al.*, 2015). The intensive use of agrochemicals, application of sewage sludge to the agricultural land, and atmospheric deposition are the main sources of heavy metals in plants. In brief, the contamination of vegetables with heavy metals may occur during their production, transport, and marketing (Radwan and Salama 2006; Ali and Al-Qahtani 2012).

Environmental pollution by toxic heavy metals does not only elicit concern in the metropolitan cities but also in remote and rural communities where anthropogenic activities, such as mining, are taking place. Gold mining and processing have been the main sources of heavy metal contamination in the environment (Girigisu *et al.*,, 2012). The uncontrolled dissemination of waste effluents to large water bodies has negatively affected both water quality and aquatic life (Abdulrahman, *et al.*,, 2008). During the processing of the ores for gold, poisonous substances such as oxides and sulphides of heavy metal pollutants are released into the environment (Boamponsem *et al.*,, 2010).

The source of heavy metal in plant is the environment in which they grow and their growth medium (soil) from which heavy metals are taken up by roots or foliage of plants (Okonkwo *et al.*,, 2005). Plants grown in polluted environment can accumulate heavy metals at high concentration causing serious risk to human health when consumed. Moreover, heavy metals are toxic because they tend to bioaccumulate in plants and animals, bioconcentrate in the food chain and attack specific organs in the body (Akinola *et al.*,, 2006; Chatterjee and Chatterjee, 2000). Vegetables constitute an important part of the human diet since there contain carbohydrates, proteins, as well as vitamins, minerals and heavy metals. Heavy metals are one of a range of important types of contaminants that can be found on the surface and in the tissue of fresh vegetables (Bigdeli and Seilsepour, 2008). A number of elements, such as lead (Pb), cadmium (Cd), nickel (Ni), cobalt (Co), chromium (Cr), Copper (Cu) and Selenium (Se) (IV) can be harmful to plants and humans even at quite low concentrations (Bowen, 1979). Soil pollution is caused by misuse of the soil, such as poor agricultural practices, disposal of industrial and urban wastes, etc. (Buchaver, 1973).

Soil is also polluted through application of chemical fertilizers (like phosphate and Zn fertilizers), and herbicides (Demi˙rezen and Aksoy, 2004). Heavy metal accumulation in soils is of concern in agricultural production due to the adverse effects on food quality, crop growth (Ma *et al.*,, 1994) and environmental health.

The growing population and increasing anthropogenic activities which include unrestricted use of herbicides and pesticides for agricultural practices, artisanal mining and quarrying and other environmental degrading activities in the communities had exposed the study area to the run-off of chemical substances including heavy metals of ecological concern. Bioaccumulation of heavy metals in the fish resources of River Manyara has been established (Adelakun and Kehinde, 2019; Kehinde and Adelakun, 2019). However, heavy metals concentration of leafy vegetables and soil from this river which serves as irrigation purposes have not been established.

Materials and Methods

Collection of samples

Samples of vegetables (Amanrathus and Jute) and soil were obtained from irrigation farmlands situated at Kere, Sabo and Nasarawa. They were randomly collected from different farmlands in the study locations and kept in properly labeled polythene bags and taken to the laboratory for processing and analysis. Samples were washed with tap water to remove any soil particles and rinsed with distilled water. The edible portions of the vegetable samples were air-dried in the open laboratory for twenty four hours to reduce the water content. Thereafter, all the samples were oven-dried at 70°C for 24 h. The dried samples were then pulverised using a pestle and mortar, sieved with muslin cloth and stored in airtight containers until required for digestion.

Digestion of samples

1g each of the pulverized samples from each sampling site was weighed and placed in crucibles. Each sample was digested using a mixture of trioxonitrate (V) acid, (HNO3) monoxochlorate (I) acid (HOCl) and hydrochloric acid (HCl) in the ratio of 1:6:1 respectively. Hot plates were used in heating the samples with intermittent addition of 3 ml of the digestion mixture until white precipitate was obtained. The digested samples were dissolved in 2 ml of trioxonitrate (V) acid for 10 mins, removed and allowed to cool and then transferred into 100 ml volumetric flask and made up to the mark with distilled water. For water samples, 20 ml of water samples were mixed with 2.5 ml of HNO3 before analysis for heavy metals using Atomic Absorption Spectrophotometer (AAS).

Statistical Analysis

Results were presented as means ± SD, where n equals the number of plant samples. Results from all the specimens are compared using ANOVA and $p < 0.05$ is considered to indicate statistical significance.

Results and Discussion

Table 1 revealed the mean heavy metals concentration in soil samples collected at different farmlands in the study area and it showed the presence of all heavy metals tested (Pb, Cr, Zn, Cu and Cd) at varying concentrations ($p<0.05$) across the sampling stations. Zn is highly concentrated at the three farmlands with highest concentration at farmland B (7.90 ± 0.00 mg/kg^{-1}), followed by Cr which recorded the highest concentration at farmland C with a mean of 1.90±0.00 mg/kg^{-1}. Pb recorded the highest concentration at farmland B with a mean of 0.40±0.07 mg/kg^{-1}while the least concentration was recorded at farmland C with a mean of 0.10±0.00mg/kg^{-1}. Cd recorded the lowest heavy metal concentration among the metals tested with the least concentration at farmland C with a mean of 0.02±0.04mg·kg^{-1}.

Table 1: Mean Heavy Metals concentration in Soil Samples (mg/kg^{-1})

Metals	Farmland **A**	Farmland **B**	Farmland **C**
Cd	0.08±0.05^{a}	0.06±0.08^{b}	0.02±0.04^{c}
Cr	1.10±0.00^{ab}	1.20±0.00^{b}	1.90±0.00^{a}
Cu	0.20±01^{a}	0.10±0.00^{b}	0.10±0.00^{b}
Pb	0.30±0.00^{b}	0.40±0.07^{a}	0.10±0.00^{c}
Zn	2.60±0.01^{b}	7.90±0.00^{a}	2.17±0.06^{c}

Note: Values are mean values ± standard deviation
Mean with different superscript within the same row are significantly different ($P<0.05$)

Table 2 indicated the heavy metal concentrations of the two selected vegetables in the study area, in which all the two vegetables samples have shown bioaccumulation for all analyzed metals with Amaranthus having the highest concentration of Zn (23.70 ±0.00 mg/kg), Cu (1.60±0.00 mg/kg) and Cd (0.24±0.06 mg/kg) of all samples while Jut had the highest concentration of Cr (4.90±0.00mg/kg). The concentration of Pb ranges from 0.30-0.40 mg/kg in all the samples.

Table 2: Heavy metal concentrations of leafy plants and soil in the study area

Farmlands	**Samples**	**Cd**	**Cr**	**Cu**	**Pb**	**Zn**
Farmland A	Amaranthus	0.19±0.1^{b}	0.60±0.00^{d}	1.60±0.00^{a}	0.30±0.00^{b}	21.40±0.00^{b}
	Jute	0.20±0.06^{ab}	1.09±0.01^{b}	1.20±0.00^{b}	0.39±0.03^{a}	7.03±0.07^{c}
Farmland B	Amaranthus	0.18±0.03^{a}	0.63±0.05^{c}	0.60±0.00^{cd}	0.40±0.01^{a}	23.70±0.00^{a}
	Jute	0.18±0.02^{b}	0.50±0.01^{e}	1.00±0.00^{c}	0.40±0.01^{a}	9.00±0.00^{bc}
Farmland C	Amaranthus	0.24±0.06^{a}	0.50±0.02^{e}	0.24±0.30^{e}	0.39±0.01^{a}	11.23±0.05^{b}
	Jute	0.21±0.01^{ab}	4.90±0.00^{a}	0.40±0.00^{d}	0.40±0.01^{a}	5.80±0.00^{d}
	P-value	0.003	0.000	0.004	0.001	0.000
	WHO/FAO (2001)Permissible Limit (mg/Kg)	0.02	21.11	2.00	0.03	99.4

Note: Values are mean values ± standard deviation
Mean with different superscript within the same row are significantly different (P<0.05)

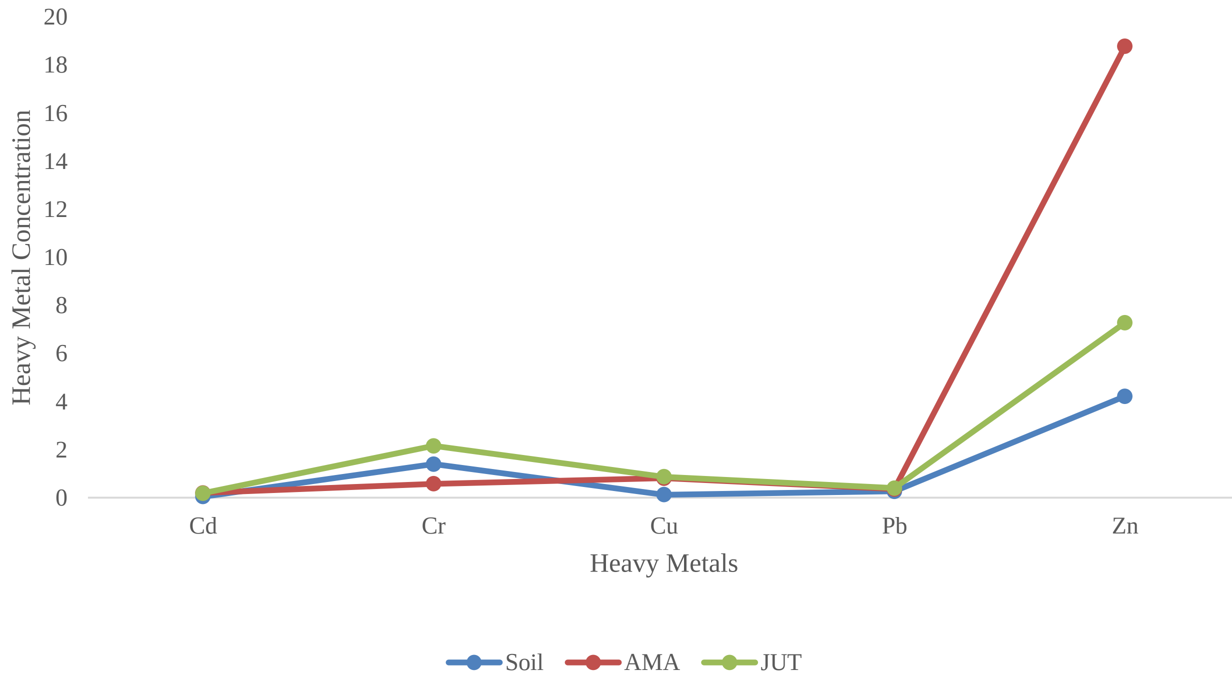

Figure 1: Comparative study of heavy metal concentrations in Soil, Amaranthus and Jute in the Study Area

The comparative study of the heavy metal concentrations in soil, Amaranthus and Jute are presented in Table 4, Zinc (Zn) recorded the highest, followed by Chromium (Cr) while Copper (Cu), Lead (Pb) and Cadmium (Cd) were the least. The correlation between the different heavy metals accumulated within the samples are presented in Table 4, Cd showed a positive correlations with others heavy metals. Cr showed a negative correlation with Cu, Pb and Zn. Also Cu, Pb and Zn showed a negative correlation with Cr.

Table 4: Correlation between different heavy metals accumulated within the samples

HEAVY METALS	Cd	Cr	Cu	Pb	Zn
Cadmium (Cd)	1	0.019	0.479*	0.657**	0.437*
Chromium (Cr)	0.019	1	-0.285	-0.051	-0.409
Copper (Cu)	0.479	-0.285	1	0.209	0.522**
Lead (Pb)	0.657**	-0.051	0.209	1	0.327
Zinc (Zn)	0.437*	-0.409*	0.522**	0.327	1

**Correlation is significant at the 0.01 level (2-tailed).
*Correlation is significant at the 0.05 level (2-tailed).

Discussion
Soil and Vegetables accumulate various contaminants that enter their environment through natural and anthropogenic activities (Adekola and Eletta, 2007; Lu *et al*.,, 2011). It has been documented that the study area has been subjected to various forms of

degradation due to pollution caused by anthropogenic activities from artisanal mining, agricultural complexes, bush burning, untreated sewage discharge, wild animal feacals and decomposed carcass (Adelakun and Kehinde, 2019; Kehinde and Adelakun, 2019) and Vegetables could uptake most of these pollutants including heavy metals through structural parts because of their fast growth and high biomass (Adesuyi *et al.*,, 2018; Singh *et al.*,, 2017).
Heavy metals can have different bioavailability to vegetables because of physiological differences with respect to uptake sites and uptake mechanisms (Jha *et al.*,, 2016) from soil where metals either settled or accumulated (Ishaq and Khan, 2013). Therefore, soil geochemistry influences metal speciation in soils while plant physiology and genotypic differences control the ability of plants to accumulate plant-available forms of metals (Singh *et al.,* 2017).
Heavy metals affect the nutritive contents of agricultural products and also have a harmful effect on humans especially when permissible limits are exceeded. National and international regulations on food quality set the maximum permissible limit of toxic metals in human food; hence an essential aspect of food quality should be to regulate the concentrations of heavy metals in food (Radwan and Salama, 2006; Sobukola *et al.*, 2007). Given the growing demand for fruits and vegetables, their heavy metal content needs to be monitored. From the current study, Heavy metals concentration in sampled soil and vegetables showed varying accumulation values, which could be attributed to the differences in their morphology and physiology for heavy metal uptake, exclusion, accumulation, and retention (Tom *et al.*, 2014). Consequently, it can be concluded that the soil features seem not to have a role in the differences observed between vegetables.

The high values of Zn obtained from the study may be from effluents eliciting from the artisarnal mining site which is in agreement with Huseyinnova *et al.*, (2009) that asserted that heavy metals spread as a results of human activities leading to an excess accumulation that exceed the permissible limits causing serious environmental disaster. Zinc is one of the most essential metals for normal growth and development in humans (Divrikli *et al.*,, 2006). Zinc deficiency is of growing concern in developing countries. Excess Zinc can also be harmful, and cause Zinc toxicity. Such toxicity levels have been seen to occur at ingestion greater than 225 mg/kg of Zinc. The concentration of Zinc in all the samples analyzed from the three farmlands was observed to be below the WHO permissible limit of 99.4 mg/kg as reported by WHO (2001). Kihampa *et al.*, (2011) reported a high Zinc concentration ranging between 18.16 and 122.88mg/kg in *Amaranthus* species. Zinc (Zn) accumulation in high amounts can cause eminent health problems, such as stomach cramp, skin irritation, vomiting, nausea and anemia (Wuana and Okieimen, 2011).

Copper is the third most used metal in the world (Volatile Corrosion Inhibitor, 2011). Copper is an essential micronutrient required in the growth of both plants and animals. The concentration of Cu in all the samples analyzed from the three farmlands was lower than the World Health Organization (WHO) permissible limit of 2.00 mg/kg. The highest levels of Cu were observed in Amaranthus (1.60 mg/kg). The results obtained were observed to be lower compared to the report of Radwan and Salama (2006) that report 2.51 in leafy vegetables, although were similar to Wang *et al.*, (2005) that reported 0.60 mg/kg in Tianjin-China.

Cadmium is a non-essential element in foods and naturalwaters and primarily it accumulates in the kidneys and liver (Divrikli *et al.*,, 2006). In all the samples analyzed from the study area, the concentration was observed to be above the permissible limit of 0.02 mg/kg as reported by World Health Organization (2001), which might be a treat for human consumption. It was highest in Amaranthus with a value of 0.24 mg/kg. Al-jassir *et al.*, (2005) reported that levels of Cd were higher in the garden rocket vegetable species for both washed and unwashed samples. Cd had been reported to be ecotoxicological concern when biomagnified in animal tissues, Cd possesses inhibitory capabilities, i.e it can block calcium channels or metabolism thereby disrupting the electrolytes balance and causing the excretion of calcium which can lead to brittle bones (Larison, 2001).

Lead(Pb) is a harmful metal that has no known vital or beneficial effect on organisms and its accumulation over time in the bodies of animals and humans can cause serious ailments (Binkowski, 2012). The concentration of lead ranges from 0.30-040 mg/kg and they are above the permissible limit of 0.03 mg/kg established by WHO (2001).Pb may enter the atmosphere during mining, smelting, refining, manufacturing processes and by the use of lead containing products (Abd EI-Salam *et al.*,, 2013). Also Divrikli *et al.*, (2006) reported that Pb can enter into the human system through air, water and food and cannot be eliminated through fruits and vegetable washing. The traces of lead found in the vegetables sample might be linked to the concentration in the polluted area and also the consequence of lead emission from petrol in the area where these vegetables were cultivated and sold (Zhen, 2008).

Conclusion

The study has confirmed that heavy metals concentrations in soil and vegetables in the study area varies significantly. The leafy vegetables have shown capacity to accumulate substantial metals which reflected the pollution status of the study area. The mean concentration of cadmium and lead levels in the vegetables were above the WHO permissible limit while the concentration of zinc, copper and chromium were below the recommended limit. These low concentrations are still of great concern since heavy metals have bioaccumulative tendencies and biomagnification potentials along the food chain.

Recommendations

- There is need for continuous monitoring of heavy metal deposition, accumulation and contamination in the study area
- The community members should be sensitize on the public health implication of consuming heavy metals contaminated vegetables.

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