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Assessment of Heavy Metal Concentrations in Soil, *Amaranthus hybridus* and *Lactuca sativa* Grown in Nagwamatse Farm, Gusau, Zamfara State, Nigeria

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Abstract

The study was conducted to determine the concentrations of some heavy metals in soil, *Amaranthus hybridus* (spinach) and *Lactuca sativa* (lettuce) grown in Nagwamatse Farm, Gusau, Zamfara State, Nigeria. Soil, spinach, and lettuce were collected randomly in replicates from the farm. The samples were numbered accordingly and were placed in a clean polythene bag. The samples were digested and analyzed for nickel (Ni), chromium (Cr), cobalt (Co), and manganese (Mn) using Atomic Absorption Spectrophotometer (A.A.S.). Mean concentrations of Ni, Cr, Co, and Mn were obtained using one-way Analysis of Variance (ANOVA) at 5% level of significance. T – test was used to compare the mean concentrations of the heavy metals in the two different vegetables in the months of November, December and January. The high concentrations of Mn (2.71 – 3.78mg/kg), Co (1.80 – 1.90 mg/kg), Ni (1.67 – 1.74mg/kg and Cr (0.91 – 1.39mg/kg) were found in *A. hybridus* while the low concentrations of Mn (2.89 – 3.45mg/kg), Co (1.76 – 1.84mg/kg), Ni (1.56 – 1.65mg/kg and Cr (0.43 – 1.24mg/kg) were found in *L. sativa,* which are found to be above the permissible limits of FAO/WHO (2011). In the soil, Mn had the highest concentration of 20.25mg/kg, Co (14.25mg/kg), Ni (10.05mg/kg), and Cr (7.23mg/kg) in the month of January than other months. Based on these findings, *A. hybridus* and *L. sativa* from the farm may pose risk health risks related to heavy metal toxicities when consumed. Phytoremediation of the soil should be done to reduce heavy metal concentrations in the soil that transfer into the vegetables grown in the soil.

Keywords: *Amaranthus hybridus* (Spinach), Assessment**,** Concentration**,** Heavy metal, *Lactuca sativa* (Lettuce), Soil.

1.0 Introduction

Heavy metals are generally referred to as metals with a specific density of over 5 g/cm^3, and adversely affect the environment and living organisms [1]. Some heavy metals are micronutrient which at low concentrations are beneficial to animals and plants but at high concentrations are toxic to both animals and plants at high concentrations [2]. For instance, copper (Cu), chromium (Cr), fluorine (F), molybdenum (Mo), nickel (Ni), selenium (Se), and zinc (Zn) are beneficial at minute quantities. Other trace elements such as arsenic (As), cadmium (Cd), mercury (Hg) and lead (Pb) are toxic even at small concentrations [3]. Heavy metals, being persistent and non-biodegradable, can neither be removed by normal cropping nor easily leached by rain water [4]. They might be transported from soil to ground waters or may be taken up by plants, including agricultural crops [5]. For this reason, the knowledge of metal-plant interactions is important for the safety of the environment [6]. The quality of ecosystem becomes altered, when heavy metals find their way, somehow, into it through human and natural activities. These activities are one of the most pressing concerns of urbanization in developing countries like Nigeria, which result in the problem of solid, liquid and toxic waste management. Such waste may be toxic or radioactive [7]. Such waste management problems include heaps of uncontrolled garbage, roadsides littered with refuse, streams blocked with rubbish, prevalence of automobile workshops and service stations, inappropriately disposed toxic waste and disposal sites that constitute a health hazard to residential areas [7]. *Amaranthus hybridus* and *Lactuca*

sativa are popular and commonly grown vegetable among farmers in Northwest of Nigeria. This vegetable species is mostly consumed because it constitutes essential diet components such as protein, vitamins, iron, calcium, and other nutrients which are usually in short supply [8]. However, the vegetable takes from the soil contaminated with toxic elements over a wide range of concentrations, poses a direct threat to human health when consumed [9]. Balkhair and Ashraf [10] reported that the vegetable takes up metals by absorbing them from contaminated soils, as well as from deposits on different parts of the vegetables exposed to the air from polluted environments. It has been reported that nearly half of the mean ingestion of lead (Pb) and cadmium (Cd) through food is due to plant origin (fruit, vegetables and cereals) [11]. Moreover, certain people, especially vegetarians, seem to be more exposed since they consume more vegetables on a daily basis [12]. Food contamination by heavy metals depends both on their mobility in the soil and their bioavailability. Though some of the mobility and bioavailability are easy to measure or modeled, determination of food risk contamination is tricky [13]. Nevertheless, the transfer of contamination through the food web is critical to predict the exposure of humans to infection and the possible health consequences of such exposure, which will assist in making an accurate risk assessment for food safety purposes. Vegetable such as spinach and lettuce are widely consumed in Nigeria, and they are highly valued due to the quality and amount of nutrients and mineral elements they contain [14]. The current high demand for leafy vegetables like spinach and lettuce have stimulated the growth of market gardening along perennial rivers, streams and waste places rich in heavy metals in major towns and cities of Nigeria. Most heavy metals are extremely toxic when contaminated spinach and lettuce are consumed and hence the need to carry out this research to ascertain the level of their concentration. World Health Organization (WHO) estimates that about a quarter of the diseases facing mankind today occur due to prolonged exposure to environmental pollution [15]. Heavy metal pollution of the environment, even at low levels, and their resulting long-term cumulative health effects are among the leading health concerns all over the world [16]. The aim of this research was to assess some heavy metals concentration presents in the soil, *A. hybridu*s and *L. sativa* grown in Nagwamatse Farm, Gusau, Zamfara State, Nigeria. The objectives are to determine the concentrations of heavy metals in soil, *A. hybridu*s and *L. sativa* grown in Nagwamatse Farm, Gusau, Zamfara State, Nigeria in the three months studied and to compare the accumulation level of heavy metals concentration in *A. hybridu*s and *L. sativa* grown in Nagwamatse Farm, Gusau, Zamfara State, Nigeria.

2.0 Materials and Methods

2.1 Study area

The study was carried Nagwamatse Farm in Gusau, Zamfara State, Nigeria (longitude 12°10'12.86" N and latitude 6°39'50.83" E). Zamfara is located in north - western Nigeria. It is home to a diverse range of ethnic groups. Some of the major ethnic groups in the state include the Hausa, Fulani, and various subgroups of the Hausa-Fulani such as the Zamfarawa, Kebbe, and Gobirawa. Zamfara State typically experiences a tropical savanna climate. This means that it has a wet season and a dry season. The wet season usually lasts from April to October, with the highest rainfall occurring between June and September. The dry season, which is characterized by hot temperatures and little to no rainfall, typically lasts from November to March. During the dry season, temperatures can rise quite high, sometimes reaching over 40°C (104°F), while during the wet season, temperatures are generally cooler due to cloud cover and rainfall. The study was conducted for a period of three months (November and December, 2023 and January, 2024),

2.2 Sample collection

Whole parts of Spinach and lettuce were collected at random in replicates in the farm for three months (November and December, 2023 and January, 2024), while the soil samples were collected at the same spot were the vegetables were collected for the same periods at a depth of 15 – 30cm [17]. They were collected in replicates at each spot. The samples were numbered accordingly and were placed in a clean polythene bag. They were brought to the laboratory, Department of Biological Sciences, Federal University Gusau for preparation.

3.3 Sample preparation

The leaves were removed from the stem. They were properly washed using tap water to remove

the soil particles and debris then rinsed with distilled water. They were air dried for 72 hours, followed by oven drying for 24hrs at 105°c. The dried leaf samples were ground using porcelain mortar and pestle, and were passed through a 2mm sieve to obtain fine powder, and then stored at room temperature for further analysis. The soil samples were also sun-dried and sieved to obtain a fine powder.

3.4 Sample digestion

Five gram (5g) of the powder of the prepared vegetables and soil were put into a 25ml conical flask separately. Five (5) ml of concentrated H_2SO_4 was added, followed by 25ml of concentrated HNO_3 and 5ml of concentrated HCl in each of the flask containing the samples. The contents of the tube were heated at 200°c for 1 hour and then cooled to room temperature, 20ml of distilled was added, filtered using filter paper to complete the digestion of organic matter. The mixture was transferred into a 50ml volumetric flask filled to mark and let to settle for at least 15 hours. The resultant supernatants were used for analyses of the heavy metals [18].

3.5 Sample analyses

The digested samples of the soil and vegetables were analyzed for nickel (Ni), chromium (Cr), cobalt (Co) and manganese (Mn) as described by Bakare and Adeyinka [19] using the Analyst 200 Perkin Elmer Atomic Absorption Spectrophotometer (A.A.S.).

3.6 Data analyses

Mean concentrations of Ni, Cr, Co and Mn were obtained using one – way analysis of variance (ANOVA) at 5% level of significance. Where significant difference was observed, Duncan's Multiple Range Test (DMRT) was used to separate the means. T – test was used to compare the mean concentrations of the heavy metals in two different vegetables. All analyses were performed using SAS V. 9.2 (2008).

3.0 Results

3.1 Mean concentrations (mg/kg) of heavy metals in *Amaranthus hybridus*

Table 1 shows the mean concentrations (mg/kg) of heavy metal in *A. hybridus*. There are non-significant differences in the Cr (P = 0.134) concentrations among the three months (November, December and January), there are significant differences in Mn (P = 0.049), Co (P = 0.044) and Ni (P = 0.034) concentrations among the three months. *A. hybridus* has higher concentrations of Mn (3.78mg/kg), Co (1.90mg/kg), Ni (1.74mg/kg) and Cr (1.39mg/kg) in the month of January while least concentrations of Mn (2.71mg/kg), Co (1.80mg/kg), Ni (1.67mg/kg) and Cr (0.91mg/kg) were detected in the month of November.

Table 1: Mean concentration (mg/kg) of heavy metals in *Amaranthus hybridus*

Locations	Mn	Co	Ni	Cr
November	2.71 ± 0.29^{c}	1.80 ± 0.02^{c}	1.67 ± 0.02^{c}	0.91 ± 0.10^{a}
December	3.13 ± 0.02^{ab}	1.86 ± 0.01^{ab}	1.71 ± 0.01^{ab}	1.17 ± 0.04^{a}
January	3.78 ± 0.07^{a}	1.90 ± 0.02^{a}	1.74 ± 0.01^{a}	1.39 ± 0.18^{a}
P - Values	**0.049***	**0.044***	**0.034***	**0.134^{ns}**
FAO/WHO (2011)	**0.20**	**10.00**	**10.00**	**1.30**

Means with different superscript letter (s) along the same columns were significantly different (p>0.05)
Key – * - Significant; ns – non significant; Cd – Cadmium, Cu – Cupper, Pb – Lead, Zn – Zinc; FAO/WHO (2011) Permissible Value in Plants (mg/kg)

3.2 Mean concentrations (mg/kg) of heavy metals in *Lactuca sativa*

Table 2 reveals the mean concentrations (mg/kg) of heavy metals in *L. sativa*. There are non-significant differences in the Cr (P = 0.116) concentrations among the three months (November, December and January), there are significant differences in Mn (P = 0.037), Co (P = 0.037) and Ni (P = 0.044) concentrations among the three months. *L. sativa* have higher concentrations of Mn (3.45mg/kg), Co (1.84mg/kg), Ni (1.65mg/kg) and Cr (1.24mg/kg) in the month of January while the least concentrations of Mn (2.89mg/kg), Co (1.76mg/kg), Ni (1.56mg/kg) and Cr (0.43mg/kg) were observed in the month of November.

Table 2: Mean concentrations (mg/kg) of heavy metals in *Lactuca sativa*

Locations	Mn	Co	Ni	Cr
November	2.89±0.01[b]	1.76±0.01[c]	1.56±0.01[c]	0.43±0.33 [a]
December	2.96±0.00[b]	1.80±0.01[ab]	1.59±0.01[ab]	1.11±0.01[a]
January	3.45±0.15[a]	1.84±0.02[a]	1.65±0.01[a]	1.24±0.09 [a]
Mean ± SE	**3.10±0.05**	**1.80±0.01**	**1.60±0.00**	**0.93±0.14**
P - Values	**0.033***	**0.037***	**0.044***	**0.116[ns]**
FAO/WHO (2011)	**0.20**	**10.00**	**10.00**	**1.30**

Means with different superscript letter (s) along the same columns were significantly different (p>0.05)
Key – * - Significant, ns – non significant; Cd – Cadmium, Cu – Cupper, Pb – Lead, Zn – Zinc; FAO/WHO (2011) Permissible Value in Plants (mg/kg)

3.3 Comparison between the mean concentrations of heavy metals (mg/kg) in *Amaranthus hybridus* and *Lactuca sativa*

The comparison shows that *A. hybridus* had the highest mean concentrations of heavy metals with concentrations of Mn (3.31mg/kg), Co (1.86mg/kg), Ni (1.70mg/kg) and Cr (115mg/kg) while *L. sativa* had the least mean concentrations of heavy metals with concentrations of Mn (3.10mg/kg), Co (1.80mg/kg), Ni (1.60mg/kg) and Cr (0.92mg/kg).

Table 3: Comparison between the mean concentrations of heavy metals (mg/kg) in *A. hybridus* and *L. sativa*

Heavy Metals	*Amaranthus hybridus* (Mean ± SEM)	*Lactuca sativa* (Mean ± SEM)
Manganese	3.31±0.17[a]	3.10±0.12[a]
Cobalt	1.86±0.02[a]	1.80±0.01[a]
Nickel	1.70±0.02[a]	1.60±0.02[a]
Chromium	1.15±0.10[a]	0.92±0.18[b]

Means with different superscript letter(s) along the same row were significantly different (p>0.05)

3.4 Mean concentrations (mg/kg) of heavy metals in the soil

Table 4 presents the mean concentrations (mg/kg) of heavy metal in the soil. There are significant differences in Mn (P = 0.015), Co (P = 0.019) and highly significant differences in Ni (P = 0.000) and Cr (P = 0.000) concentrations among the three months. Mn had the highest concentrations of 20.25mg/kg, Co (14.25mg/kg), Ni (10.05mg/kg) and Cr (7.23mg/kg) in the month of January while the least concentrations of Mn (17.47mg/kg), Co (13.05mg/kg), Ni (9.13mg/kg) and Cr (5.14mg/kg) were detected in the month of November.

Table 4: Mean concentrations (mg/kg) of heavy metals in the soil

Locations	Mn	Co	Ni	Cr
November	17.47±0.47[b]	13.05±0.02[b]	9.13±0.02[b]	5.14±0.04[c]
December	18.13±0.25[b]	14.16±0.05[a]	9.91±0.01[a]	6.00±0.00[b]
January	20.25±0.25[a]	14.25±0.25[a]	10.05±0.05[a]	7.23±0.03[a]
Mean ± SE	**18.61±0.32**	**13.82±0.31**	**9.70±0.07**	**6.12±0.04**
P - Values	**0.015***	**0.019***	**0.000****	**0.000****
FAO/WHO (2011)	**500**	**0.1 - 50**	**2 - 40**	**1.3**

Means with different superscript letter (s) along the same columns were significantly different (p>0.05)
Key – * - Significant, ns – non significant; Cd – Cadmium, Cu – Cupper, Pb – Lead, Zn – Zinc; FAO/WHO (2011) Permissible Value in Plants (mg/kg)

4.0 Discussion

4.1 Mean concentration (mg/kg) of heavy metals in *A. hybridus* and *L. sativa*

The study on the determination of some heavy metal concentrations in *A. hybridus* and *L. sativa* was carried out during the months of November and December, 2023 and January, 2024. The heavy metal concentrations determined during the

study were: Mn, Co, Ni, and Cr. The highest mean concentrations of the Mn, Co, Ni and Cr were found in the month of January, while the least were found in the month of November in both the two plants (*A. hybridus* and *L. sativa*). It was observed that the pattern of rainfall is in the order of: November 2023 > December 2023 > January 2024. Highest concentrations of all the heavy metals determined (Mn, Co, Ni and Cr) occurred in the month of January, followed by December and the least were found in the month of November. The highest concentrations in the month of January could be as a result of less amount of rainfall than other two months, decrease in the amount of rainfall tends to concentrate more heavy metals, while the least amount present in November could be as a result of high amount of water in the soil than the other months and the runoff effect that is capable of removing heavy metals from the farmland and the effect of rainfall which may facilitate the leaching of the soil and contributes to the dilution of soil solution which leads to significant reduction/decrease in the heavy metal concentrations in *A. hybridus* and *L. sativa.*

Villares et al. [20] reported that high rainfall reduces the amount of heavy metals present in soil and also causes reduction in the absorption ability of the plants. The sequence of metal concentrations in *A. hybridus* and *L. sativa* cultivated in Nagwamatse Farm, Gusau was Mn > Co > Ni > Cr. However, the heavy metals found to be below the permissible limits by FAO/WHO [21] standard during the months of November, December and January were Co and Ni in *A. hybridus* and Cr in *L. sativa* and Cr in the months of December and November, while Mn concentrations were above the permissible limits of FAO/WHO [21] standard in both *A. hybridus* and *L. sativa* in the three months as well as Cr only in the month of January (1.39mg/kg) in *A. hybridus*. The heavy metals with values above the permissible limits could pose a great risk to the consumers. Riar et al. [22] observed similar findings and discovered that heavy metals with concentrations above permissible limits could affect both plants and animals when the vegetables are consumed. Similar findings were also observed by Salau et al. [23] that worked on the assessment of heavy metal assessment of *Azadirachta indica* (L.) in the removal of heavy metal from soil contaminated with lead poisoning in Anka, Zamfara State and discovered high concentrations of some heavy metals which could affects both plants and animals.

4.2 Variations in the mean concentration (mg/kg) of heavy metals in the *A. hybridus* and *L. sativa*

The significant variations were observed in the level of heavy metal accumulation between *A. hybridus* and *L. sativa,* with high heavy metal accumulation in *A. hybridus* and low in *L. sativa*. The high concentrations of the heavy metals in *A. hybridus* could be as a result of high absorption, translocation as well as bioaccumulation of heavy metals in *A. hybridus* than in *L. sativa,* which could also be associated with genetic differences [24]. It has reported that *A. hybridus* is a very good heavy metal accumulator than *L. sativa* [25]. This is in line with the findings of Awino et al. [26], who discovered different variations in the heavy metal concentrations between two different vegetables and associated the variation with plant species, plant parts and metal species as well as rate of translocation.

4.3 Mean concentrations (mg/kg) of heavy metals in the soil

The mean concentrations of the heavy metals studied (Mn, Co, Ni and Cr) were found to be higher during the month of January, 2024, this could be as a result of reduced amount of water in the soil than the month of November when there is more heavy rainfall. It may be be as a result of domestic wastes, excessive fertilizers and pesticides, field traffic, and automobile exhaust in the soil. Similar results were obtained by Norouzi et al. [27] who studied the seasonal and spatial variations in dust deposition rate and concentrations of dust-borne heavy metals dust samples collected each month from January and discovered that all the metals were higher than December and November, 2023.

5.0 Conclusions

The high concentrations of Mn (2.71 – 3.78mg/kg), Co (1.80 – 1.90 mg/kg), Ni (1.67 – 1.74mg/kg and Cr (0.91 – 1.39mg/kg) were found in *A. hybridus* while the low concentrations of Mn (2.89 – 3.45mg/kg), Co (1.76 – 1.84mg/kg), Ni (1.56 – 1.65mg/kg and Cr (0.43 – 1.24mg/kg) were found in *L. sativa* which were found to be above the permissible limits of FAO/WHO (2011). *A. hybridus* and *L. sativa* may pose risk of heavy metals toxicity when consumed while Mn had the highest concentration of 20.25mg/kg, Co (14.25mg/kg), Ni (10.05mg/kg) and Cr (7.23mg/kg) in the month of January while least

concentrations of Mn (17.47mg/kg), Co (13.05mg/kg), Ni (9.13mg/kg) and Cr (5.14mg/kg) in the month of November in the soil. *A. hybridus* had the highest mean concentrations of Mn (3.31mg/kg), Co (1.86mg/kg), Ni (1.70mg/kg and Cr (1.15mg/kg) while *L. sativa* had the least mean concentrations of Mn (3.10mg/kg), Co (1.80mg/kg), Ni (1.60mg/kg and Cr (0.92mg/kg). This indicates that *A. hybridus* might have high toxic levels of heavy metals than *L. sativa* and the heavy metals should therefore be discourage from consuming as they can lead to toxic effects on animals and humans when consumed.

6.0 Recommendations

Phytoremediation of the soil should be done to reduce heavy metal concentrations in the soil that transfer into the vegetables grown in the soil.

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8.0 Conflict of Interest

There is no conflict of interest.

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