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The Study on the Heavy Metal Concentrations and Translocations in *Moringa Oleifera* (*Moringaceae)* Plants and Soil of Potiskum Metropolis, North Eastern Nigeria

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ABSTRACT

*In recent times, the heavy metals pollution in the environment through soil, plant and air has increasingly gathered global concern. The aims of this study is to determine the heavy metals concentrations in the root, stems and leaves of Moringa oleifera plants and the soil sample of Potiskum metropolis as the plant is widely getting popularity and acceptance for used medicinally to cure different ailments in humans and also to compute the translocation factor from different sites. The heavy metals such as (lead, cadmium, zinc and iron) were determined using Atomic Absorption Spectrometry method. Results from different sample of M. oleifera showed the highest mean concentrations of the following heavy metals from different parts of M. oleifera , for cadmium root (Jigawa Cd= 0.007±0.001 ppm),lead leaves (Nahuta Pb = 0.100 ±0.021 ppm), Zinc and Iron from the leaves and stem of samples (Arikeme Zn = 0.063±0.001 ppm and Fe = 2.464±2.393ppm) respectively. Also, the soil samples, with the highest mean concentrations of cadmium and lead was obtained from Jigawa soil and were (Cd = 0.007±0.000 ppm and Pb = 0.080±0.009 ppm) respectively. Also for the Zinc and Iron recorded at Mamudo soils were (Zn = 0.032±0.014 ppm and Fe= 5.468±0.753 ppm) respectively. Moreover, the translocation factor (T_f), for the Cd in all the study areas were recorded ($T_f \leq 1$) except in Jigawa ($T_f \geq 1$), the lead T_f values reported for all study sites was ($T_f < 1$) and that of Arikeme site ($T_f \geq 1$). While for the Zn and Fe T_f values of all study sites were recorded reciprocal as ($T_f \geq 1$) and ($T_f \leq 1$) respectively. It was concluded that the heavy metals in M. oleifera plants and soil samples of all the study areas are safe for humans as outlined by FAO/WHO***.**

Keywords: Soil, Heavy Metals, *Moringa oleifera*, Translocation factor, Atomic Absorption Spectrometry

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INTRODUCTION

Over decades, human being has relied abundantly on medicinal plants for health and food needs, as a result, the study of heavy metal pollution in plant and soil plays a vital role for health safety [1]. Heavy metal in terms of specific gravity and atomic weight are metals with density greater than 3.5 -5 g/cm^3 and with a high atomic weight [2].The interactions of heavy metals with soil and water as sources contaminants in our immediate environment, may be due to either natural and/or anthropogenic activities which is hazardous to our health. Therefore, it is necessary to protect the environment from the influx of such contaminants through water, soil, plant etc [3]. Numerous studies have reported the effect of heavy metals in plants [4 - 6].The effect of heavy metal toxicity depends on the types of element found in the plant .Heavy metal toxicity may lead to reductions in plant height and can affect growth of some parts or whole plant [7 - 9]. Studies showed that the morphological and structural effects seen in plants due to heavy metals toxicity in plant such as reduction of roots population, tip damage, reduction in root growth, and root hair collapse [10, 11].

M. oleifera (family name:*Moringaceae*). Is a useful tree and traditionally called miracle tree. It may serve as food and medicine. It is rich in proteins, minerals, vitamins, folic acid and β-carotene [12]. Every part of *M. oleifera* plant such as roots, fruits, leaves, stem is used as food because of it high nutritional content. Also, for medicinal purposes, it is used as a drug for the treatments of several ailments such as diabetes, asthma, bacterial diseases, and has proven to have an antioxidant, antiflammatory, antifungal, antibiotic and antimicrobial activities [13 -15].

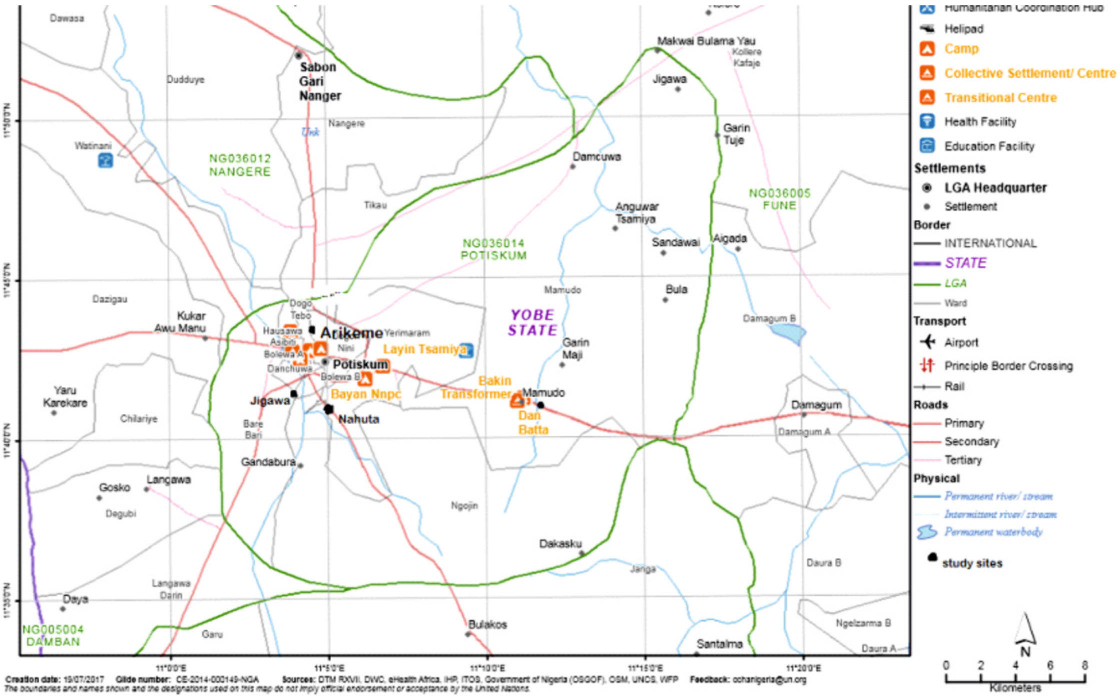
A study by [16], recorded the following concentrations of heavy metals in various part of *M. oleifera* samples Fe = (115.352-469.089 mg/kg), Zn = (41.326-139.79 mg/kg), Cd = (0.068-0.182 mg/kg) and Pb = (1.175-3.285 mg/kg) in the leaves, capsules and seed of M. *oleifera* Using similar analytical approach [12]. The concentration of heavy metal in the samples of *M. oleifera* of Agra and Aligarh as documented for zinc is 9.973 and 8.241 ppm in the sample of Aligarh respectively, cadmium in the stem bark of Agra is 0.485ppm and 0.548 ppm, in the sample of Aligarh, lead in stem bark sample of Agra is 0.295 ppm and 0.311 ppm in the sample of Aligarh and for iron in stem bark sample of Agra is 204.86 ppm and 180.769 ppm in a sample of Aligarh. Also another study showed that heavy metals might likely to translocate into the soils, when waste water is used to irrigate crops. Also, [17] showed that the heavy metal concentrations (mg kg^{-1}) in soils under vegetables in Harare, Zimbabwe ranged from 14 to 228 for Zn, 0.5 to 3.4 for Cd, and 4 to 59 for Pb respectively.

Determinations of Heavy metals such as Lead, Chromium and Cadmium have been carried out all over the world using various analytical techniques [18].The heavy metals translocation from soil to the roots is measured by T_F which is defined as a ratio of mean concentration from soil to the mean concentration of root of the plant. However, if T_F is greater than one or equal to one ($T_F \geq 1$) indicate that translocation of metals successfully was made to the roots from soil[19,20].The aims of this study are to determine the mean concentrations of heavy metals such as Cadmium (Cd), Lead (Pb), Zinc (Zn), and Iron (Fe) in leaves, stems and roots of *M. oleifera* plants samples and investigate the transfer of heavy metals from soil to the roots of *M. oleifera* plants in some selected areas in Potiskum metropolis using atomic absorption spectrometry.

MATERIALS AND METHODS

Study Sites

Potiskum is a local government area in Yobe state, Nigeria, which is located on the A3 highway at 11^{0} 43΄N, 11^{0}.04΄E (latitude, longitude). It has an area of 559 square kilometer (216 Square mi) and a population of 205, 876 (2006 census). GMT time in Potiskum is plus one (+1) hour and is located in semi- arid region of Nigeria with tropical continental climate which is characterized by short wet season, from June to August and has an annual rainfall of 500-1000 mm on average, where the dry season is long from October to May, with a high temperature of about 38^{0}C to 44^{0}C annually. Potiskum is the largest city in Yobe state with booming business in the area. It has one of the large cattle market in Africa and the largest in West Africa. The following Figure 1. Showed the map of the study sites



Note: Areas highlighted bold with black square box on the above map (Arikeme, Jigawa, Nahuta and Mamudo), indicate areas within Potiskum metropolis where the plant samples and soils were collected three times each in triplicate for the analysis (Sources: Google Map; 2017).

Figure 1: The Map of the study sites in Potiskum metropolis

Sample collection

Eight (8) samples of soil and twenty four (24) samples of plants (stem, root, leaf of *M. oleifera*) were collected from four different locations in Potiskum areas of Yobe state (Nahuta, along Fika road, Arikeme along Nangere road, Jigawa, along Jos road and Mamudo, along Maiduguri road). The samples were placed in clean Polyethene bags and labeled accordingly. Three samples from each area were considered for mean concentrations and were taken into the laboratory for further analysis.

Instrument and its calibration

AAS-6800 (Shimadzu, Japan) with high resolution continuum source atomic absorption spectrometer was used. The method was based on the proper wavelengths as 228.8 nm, 283.3 nm, 248.3 nm, and 213.9 nm for Cadmium, lead, iron and zinc respectively as described by [32, 33]. All instrumental settings were adopted from manufacturer's operation manual book according the manufacturer's instruction (adopted from NARICT, Zaria). The Flame Atomic Absorption Spectrometer (AAS-6800) showed linear for the calibration curve and the linearity was evaluated with standard solutions at a concentration range of 0.0, 2.0, 4.0, and 6.0 ppm for lead (Pb) [r = 0.998], for cadmium (cd) 0.00,0.10,0.30,0.50 ppm (r = 0.9994) also for zinc (Zn) 0.00, 0.10, 0.30, 0.50 ppm (r = 0.9931) and finally, for iron (fe) 5.0,10.0,15.0,20.0,25.0 ppm (r = 0.9962) as described by [32, 33].

Soil Samples Preparation and Digestion Procedure

Collected soil samples were dried using thermostatic drying oven (DHG-9202 Gulfex medical & scientific England) at 100 ^{0}C for an hour, ground using laboratory motor and pestles, the soil samples were sieved with stainless steel strainer (< 2 mm pore size) then sample were homogenized for sample representative. Approximately 2 g of pulverized soil samples were weighed using electrical weighing balance and placed in a clean-beaker. 15 ml of each concentrated NHO_3 and HCL were added to the sample then the mixtures were taken to the hot plate at 110 ^{0}C for an hour [21]. After that, the digested sample was allowed to cool for about 20 minutes. The solutions were filtered using Whatman filter paper No. 42. Then, distilled water was added to the solutions to reach 60 ml in 100 ml graduated cylinder and at that moment the samples were ready for analysis [22].

Plant Samples Preparation and Digestion Procedure

The *M. oleifera* plant samples were washed with clean water, the roots, stems and leaves were cut using stainless steel knife. Then samples were air-dried and further placed in thermostatic drying oven (DHG-9202 Gulfex medical & scientific England) at 100 ^{0}C for 50 minutes to obtain constant weigh then the dried samples were pulverized using laboratory motor and pestles with care to avoid contamination with aerosol dust. About 2 g of powdered samples were added to the beakers followed by the addition 15 ml of each concentrated NHO_3 and HCL to the samples. The mixtures were placed on hot plate at 110 ^{0}C for 45 minutes [21].The resultant solutions were then allowed to cool for about 15 minutes. Thereafter, the solutions were filtered using What man filter paper No. 42. Distilled water was then added to the solutions to reach up to 60 ml in 100 ml graduated cylinder. All reagents used were of analytical grade [22].

Sample Analysis

Samples of plants and soil were subjected to atomic absorption spectrometer (AAS-6800 Shimadzu, Japan) to determine heavy metals such as (Cd, Pb, Zn, and Fe). The instrument setting and operational conditions were done in accordance with the manufacturers' specifications (NARICT, Zaria).

Translocation factor

The heavy metals translocation from soil to root is measured by T_F which is given below:

Table1. Mean (±SD) concentrations of heavy metals (ppm) in Leaves, Stems and Root of *M. oleifera* plant from selected sites of Potiskum

Sites	Plant parts	Cd(ppm)	Pb(ppm)	Zn(ppm)	Fe(ppm)
Arikeme	Leaves	0.003±0.002	0.063±0.042	0.063±0.001^{yy}	1.322±1.301
	Stem	0.003±0.001	0.072±0.007	0.032±0.001	2.464±2.393^{yy}
	Root	0.004±0.001	0.065±0.014	0.030±0.005	0.689±0.016
Jigawa	Leaves	0.003±0.002	0.057±0.010	0.040±0.001	0.226±0.029
	Stem	0.005±0.000	0.063±0.048	0.031±0.020	0.114±0.003
	Root	0.007±0.001^{yy}	0.030±0.004	0.030±0.009	0.683±0.090
Nahuta	Leaves	0.005±0.001	0.100±0.021^{yy}	0.040±0.012	0.293±0.065
	Stem	0.003±0.001	0.029±0.020^{xx}	0.024±0.001	0.077±0.071^{xx}
	Root	0.004±0.002	0.047±0.001	0.021±0.001^{xx}	0.317±0.093
Mamudo	Leaves	0.002±0.001^{xx}	0.053±0.010	0.023±0.010	0.128±0.054
	Stem	0.005±0.001	0.075±0.009	0.033±0.003	0.559±0.013
	Root	0.004±0.001	0.039±0.001	0.040±0.009	0.528±0.071

(±SD) standard deviation; the superscript yy indicate the highest mean concentrations of heavy metals; the superscript xx indicates the lowest mean concentrations of heavy metal in the *M. oleifera* plant of different parts.

Table 2 Mean (±SD) concentrations of heavy metals (ppm) in soil samples from the study sites of Potiskum

Sites	Cd(ppm)	Pb(ppm)	Zn(ppm)	Fe(ppm)
Arikeme	0.006±0.001	0.041±0.015^{xx}	0.015±0.001	3.889±0.486
Jigawa	0.007±0.000^{yy}	0.080±0.009^{yy}	0.009±0.006^{xx}	3.192±1.333^{xx}
Nahuta	0.005±0.000	0.050±0.033	0.014±0.006	4.809±0.065
Mamudo	0.006±0.001	0.046±0.006	0.032±0.014^{yy}	5.468±0.753^{yy}

(±SD) = standard deviation

Table 3: Show the translocation factor of heavy metals from soil to the roots of *M. oleifera* plant samples of the study sites

Sites	Translocation factor T_F			
	Cd	Pb	Zn	Fe
Arikeme	0.67	1.58*	2.00*	0.17
Jigawa	1.00*	0.38	3.33*	0.21
Nahuta	0.80	0.94	1.50*	0.06
Mamudo	0.67	0.85	1.25*	0.10

*indicates that the translocation factor is (T_F ≥1)

CADMIUM (Cd)

Tables 1 and 2, shows the cadmium mean concentrations in plants organs of *M. oleifera* and the soil samples respectively of all study sites. The highest cadmium mean concentrations was found in root of sample from Jigawa (Cd = 0.007±0.001 ppm) and the lowest was found in the leaves of sample from Mamudo (Cd =0.002±0.001 ppm).The highest cadmium content in the soil samples of all study sites was found in the sample from Jigawa (Cd = 0.007±0.000 ppm) which is similar to the value from root in the same study site (Table.1).The cadmium in soil sample from Nahuta was (Cd = 0.005±0.000ppm), while for Arikeme and Mamudo both recorded the same value of (Cd = 0.006±0.001 ppm).

The heavy metals accumulation in *M. oleifera* plant from Arikeme was in order of Root > stem > leaves. Similarly, the heavy metal toxicity pattern in the sample from Jigawa was in order of root > stem > leaves. Also, for Nahuta is leaves >root > stem. However, Nahuta results contradict the sequences of cadmium accumulation in the present study. The root as contact with the soil, so toxic elements usually accumulate more than the shoots [23, 24, 25]. The result further showed that the heavy metal pattern in Mamudo follows root > stem> leaves. It is interesting to note that the sequence is in order with the physical-structure of the *M. oleifera* plant but does not obey the linearity of the toxic accumulations. [12] reported the presence of cadmium in *M. oleifera* (Stem Bark) of Agra and Aligarh (Cd = 0.485 and 0.548 ppm) respectively which are higher than the cadmium content for this study may be the Agra and Aligarh were located in highly contaminated source such as fertilizer, oil industries etc.

This study also observed the translocation factor of cadmium as (T_F< 1) for all study sites except for Jigawa which is (T_F = 1) [Table 3]. This indicated that the cadmium transferred from soil to the root of *M. oleifera* plant in Jigawa study area. In the previous study, the translocation factor T_F for Cd in all samples from control plants was (0.01 - 0.1), while in polluted area the T_F was found to be between (0.1 - 0.5.) [20]. The results revealed that all values were similar to our findings except for Jigawa with T_F = 1.

Additionally, the previous study by [16] observed that the cadmium in various parts of *M. oleifera* samples ranging from (Cd = 0.012 - 0.355) mg/kg this is an indication that in this study the values recorded for cadmium were below the previous report in the literature [16]. However, cadmium being a dangerous pollutant due to its high toxicity content, its accumulation in plants may cause a serious health threat to human via food chain and also cause ailments to children by direct contact with the cadmium via contaminated soil [26]. Cadmium is accessible to plants through the soil and hence the toxic effects which may cause diseases to human organs such as kidney, bone marrow, and liver. It may also increase risk of fracture, carcinogenic, osteoporosis, and which may also affect bone mineralization. However, findings from this study reported that the level of cadmium in the samples was within the recommended value as set by WHO, which indicates that the *M. oleifera* plant in the study area is safe for human consumptions.

The safety limit set by World Health Organization is 0.2 to 0.81 ppm and the Joint Expert Committee on Food Additives [JECFA] and World Health Organization has recommended the PTWI as 0.007 mg/kg for cadmium [27].Thus concentration of cadmium in *M. oleifera* is within this limits.

LEAD (Pb)

Lead is one of the dangerous heavy metals that cause severe health risk. Several literatures reported on the effect of heavy metals in plants and human organs; it adversely affects the growth and height of plant parts [28]. It can be observed from Tables 3 and 4 of this study that the highest mean concentrations of lead in *M. oleifera* was recorded in leaves sample from Nahuta (Pb = 0.100±0.021 ppm) and the lowest was recorded in stem of the sample from Nahuta (Pb = 0.029±0.020 ppm).The highest mean concentration of soil sample was recorded in Jigawa (Pb = 0.080±0.009 ppm) and the lowest was recorded in Arikeme (Pb = 0.041±0.015 ppm).

In addition, the present study revealed that the lead toxicity order in *M. oleifera* plant organs are as follows: Arikeme stem > root > leaves. Also, Jigawa demonstrate the pattern as stem > leaves> root. For Nahuta recorded the pattern as leaves > root > stem and finally, the pattern of Mamudo is stem > leaves> root. The above sequences shows that the lead does not distribute orderly based on the morphological arrangement of the plant in all patterns. It is interested to note that the results from the previous literatures were somewhat closer to or higher than the results obtained in our study. Interestingly, [12] revealed the value of *M. oleifera* (Stem Bark) of Agra (Pb = 0.295 ppm) and Aligarh of India as (Pb = 0.311 ppm) and [16] reported that the lead concentration of all sample of *M. oleifera* product ranges from (Pb = 0.001 – 24.032) mg/kg.

Lead can affect plant through soil to root system. This study revealed that the translocation factor for Arikeme (T_F>1), Jigawa, Nahuta and Mamudo were all (T_F< 1). These results demonstrated that lead was transferred from soil to root of the *M. oleifera* plant of Arikeme. This transfer may occur as a result of anthropogenic activities in the study area.

The recommended value set by WHO is 0.1 to 10 ppm [12].This shows that the lead levels in the study area were all within the recommended level set by WHO. Therefore, the *M. oleifera* plant is safe for the inhabitants of the study area.

ZINC (Zn)

Results in Tables 1 and 2 represents the concentrations of heavy metal in *M. oleifera* plant and soil sample from the study area (Potiskum). It can be noted that the highest concentration of zinc was recorded in the leaves from Arikeme (Zn = 0.063±0.001 ppm) and the lowest was recorded in the root from Nahuta (Zn = 0.021±0.001 ppm). Also for soil samples, the highest zinc concentration was recorded in the soil samples from Mamudo (Zn = 0.032±0.014 ppm) and the lowest was observed in the soil from Jigawa (Zn = 0.009±0.006 ppm).

Zinc is one of the essential elements required for plant growth. The overall concentration of heavy metals in *M. oleifera* plant samples of Arikeme, Jigawa and Nahuta follows this trend; leaves > stem>root .However, for Mamudo the trend was root > stem> leaves.

The basic knowledge of sources of heavy metals transfer plays a vital role in environmental pollution. Therefore, this study revealed the translocation factor from soil to root system of *M. oleifera* plants in the study areas from Potiskum metropolis as ($T_F \geq 1$), this also demonstrate that the heavy metals were transferred from soils to the roots system of all the samples studied.

The results of the previous studies by [16] for zinc were ranged from Zn = 55.639 - 156.518 mg/kg of all analyzed samples of leaf capsules and [12] recorded the value of *M. oleifera* (Stem Bark) of Agra (Zn =9.973 ppm) and Aligarh of India as (Zn =8.241 ppm). These findings were relatively higher when compared to our results. Nevertheless, our study reported that the zinc level was within the recommended value as set by FAO/WHO (1984) Zn = 27.4 ppm [12].

Zinc being vital element in plants, Elinder, [29] reported that the plants food such as grains, vegetables, and fruit are low in zinc usually <5 mg/kg. However, WHO [30] previously reported that the Joint Expert Committee on Food Additives (JECFA) in 1982 proposed a daily dietary requisite for zinc as 0.3 mg/kg of body weight and a provisional maximum tolerable daily intake (PMTDI) of 1.0 mg/kg of body weight [31]. The daily requirement for adult humans was 15-22 mg/day. Therefore, the report of zinc concentrations for this study is not of health concern to the inhabitants living across the study areas.

IRON (Fe)

Tables 1 and 2, Presents the mean concentrations of Iron in *M. oleifera* plant and soil sample of Potiskum metropolis respectively. It can be seen that the highest concentration of iron in *M. oleifera* plant samples of Potiskum Metropolis was recorded in stem from Arikeme (Fe = 2.464 ± 2.393 ppm) and the lowest was recorded in stem of sample from Nahuta as (Fe = 0.077 ± 0.071 ppm) and also for soil samples of same study sites, the highest concentration was observed in sample from Mamudo (Fe = 5.468±0.753 ppm) and the lowest was recorded in sample from Jigawa (Fe = 3.192 ± 1.333 ppm).

The order of heavy metal accumulations in *M. Oleifera* plant is as follows, for Arikeme > stem > leaves >root. For Jigawa was root > stem > leaves, also display the same trend for Nahuta root > stem > leaves and finally for Mamudo the trend was stem > root > leaves.

The transfer factors of all the study sites were reported as in Table 3 is $T_F < 1$ this demonstrated that there is no evidence of transfer of iron from soils to the roots system of all samples from the study areas in Potiskum Metropolis.

Previous study by [12] revealed that the concentrations of Iron in *M. oleifera* plant in India for Agra (Fe =204.862 ppm) and Aligarh as (Fe =180.769 ppm). These results are higher than our findings .However, the result from this study also indicated that the Iron levels are safe for the people leaving in the studied areas.

Conclusion

The study of heavy metals in plants and soil play a vital role in determination of the toxicity level in living organism and it environments, many studies proved the negative impact of heavy metals on human health, However, from our study the concentrations of heavy metals in the study areas were within standard limit as set by the WHO and FAO. Therefore, the *M. oleifera* plants from the study area are recommended and safe for food and used for traditional medicine if the need arise.

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