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ORIGINAL ARTICLE

Evaluation of Heavy Metal Accumulation in *talinum triangulare* grown around Municipal solid waste dumpsites in Nigeria

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ABSTRACT

An evaluation of the accumulation of heavy metals (Cd, Cu, Fe, Ni, Pb and Zn) in Talinum triangulare plant around two municipal solid waste dumpsites in Gombe, Nigeria was carried out using Atomic Absorption Spectrophotometer. The average soil concentrations of the metals in the two dumpsites were in the order Fe>Zn>Pb>Cu>Ni>Cd while the order in Talinum triangulare was Fe>Zn>Cu>Pb>Ni>Cd. The result of soil enrichment factor implicated anthropogenic activities rather than lithogenic inputs as the sources of these heavy metals. The order of mobility (translocation) of the metals from root to shoot tissues is Cd>Pb>Fe>Ni>Zn>Cu while metal bioaccumulation trends in the plant are Cd>Fe>Cu>Zn>Pb>Ni for Bamuza dumpsite (DSS_1) and Cd>Cu>Fe>Zn>Ni>Pb for BCGA dumpsite (DSS_2). Thus in the two dumpsites, Talinum triangulare exhibited greatest bioaccumulation ability for Cd and least for Ni and Pb. With the exception of Cd, the roots accumulated the metals more than the shoots. The high accumulation of Cd in the shoot system is an indication of the metal's ability to be readily translocated to plant tops after absorption by the roots. Pearson bivariate correlation indicated significant positive correlations between Cd and Cu ($p<0.05$); Cu and Zn ($p<0.01$); Fe and Ni ($p<0.05$) in the whole plant. Although this study did not implicate Talinum triangulare as a hyperaccumulator plant with regard to the metals studied (Cd, Cu, Fe, Ni, Pb and Zn), its high bioaccumulation of Cd in the shoot tissues is an indication that it may be risky to consume Talinum triangulare grown on dumpsites owing to the toxicity of the metal to humans.

Key words: *Heavy metals, Accumulation, Talinum triangulare, Enrichment factor, Translocation factor.*

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INTRODUCTION

Heavy metals are among the contaminants in the environment. Beside the natural activities, almost all human activities also have potential contribution to produce heavy metals as side effects [1]. The occurrence of various heavy metals such as Mn, As, Cr, Cd, Ni, Zn, Co, Cu, and Fe in municipal solid waste (MSW) dumpsites was reported by many workers [2-6]. Some of these metals are micronutrients necessary for plant growth, such as Zn, Cu, Mn, Ni, and Co, while others have unknown biological function, such as Cd, Pb, and Hg [7]. Elevated heavy metal concentrations in the soil can lead to enhanced crop uptake. Excessive metals in human nutrition can be toxic and can cause acute and chronic diseases [8]. Cadmium and Zinc, for example, can lead to acute gastrointestinal and respiratory damage and acute heart, brain, and kidney damage. Chronic diseases have been reported in humans exposed to long-term heavy metal uptake including local effects on skin and mucous membranes and various systemic effects on the intestines [9]. Elevated heavy metal concentrations in the soil can also negatively affect crop growth. At higher concentrations, they interfere with metabolic processes and inhibit growth, sometimes leading to plant death [10-12]. Consequently, quality standards were established that determine thresholds of maximum heavy metal concentrations allowed in plant tissue. In the European Union, maximum concentrations of lead (Pb) and cadmium (Cd) allowed in several agricultural crops were recently enacted into law [13]. The assessment of heavy metal contents of plants grown on dumpsites does not only enhance the quality of life of end-users (through the provision of data on the safety and wholesomeness of such edible plants) but also provides an invaluable data on the heavy metals phytoaccumulation potentials of such plants [14, 15].

This research work is therefore aimed at evaluating the heavy metal contamination levels of two dumpsites in Gombe as well as their accumulation in *Talinum triangulare* plants grown around these dumpsites. This is in order to determine the quality of soil and the suitability or otherwise of the plant for human consumption.

MATERIALS AND METHODS

Study Area

This study was carried out at two municipal solid waste dumpsites (Bamuza and BCGA) within the city of Gombe, North-Eastern Nigeria as shown in Figure 1 below. Gombe is a centre of commercial and industrial activities in Gombe State. It is located at Latitude $9^0$30' and $12^0$30'N and Longitude $8^0$45' and $11^0$45'E, and is surrounded by hills, thereby creating natural depressions within the State. The soils are mainly sandy with few areas of clay materials. The climate is tropical with two distinct seasons (dry and rainy seasons) while her vegetation is that of Guinea Savanna. With an estimated population of 280,000 (268,000 at the 2006 census), Gombe metropolis generates large volume of wastes which are deposited at designated dumpsites. Vegetable plants are also grown by local farmers at close proximity to such dumpsites.

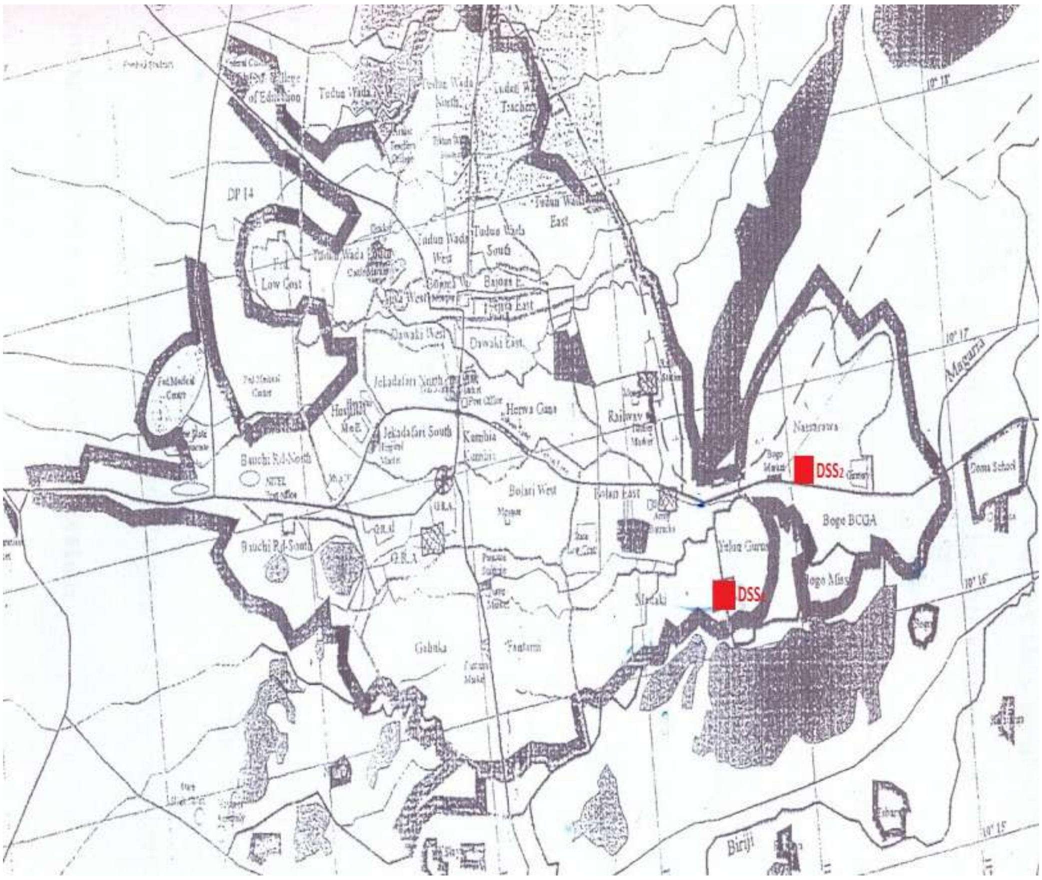

Figure 1: Map of Gombe showing the study sites (DSS_1: Bamuza; DSS_2: BCGA).

Sample Collection

The shoots and roots of *Talinum triangulare* were randomly collected at different points around two municipal solid waste dumpsites in Gombe. For each vegetable plant sampled, surrounding soil about 0-20cm was randomly collected. These samples included surface and sub-surface soils. All the samples were collected during the month of September 2013.

Sample Preparation and Digestion

The vegetable plants were cleaned to remove visible soil and then washed with tap water several times. The samples were allowed to drain, and then separated into roots and shoots, and air dried. The dried samples were ground to fine powder, sieved through a 1.5mm sieve and transferred to polyethylene bags for storage until later analysis.

Five gram of vegetable samples was weighed into a 100 cm^3 beaker and aqua regia (3:1 HCl/HNO_3) was added. The beaker was covered with a watch glass and placed on a hotplate in a fume cupboard. The mixture was boiled and allowed to simmer for 1 hour. The beaker was removed and allowed to cool. When no fumes were given off, the watch glass was removed allowing the liquid attached to it to drain into the beaker. The content of the beaker was filtered through a Whatman no. 540 filter paper into the volumetric flask using distilled water. The flask was inverted several times to achieve homogeneity of the solution [16].

One gram of the sieved soil was weighed out and transferred into a 100 cm^3 tall-form beaker. About 20 cm^3 of (1:1) HNO_3/HCl acid mixture was added and boiled gently on a hotplate until the volume of nitric acid mixture was reduced to about 5 cm^3. Then 20 cm^3 of deionized water was added and boiled gently again until the volume is approximately 10 cm^3. The resulting suspension was cooled and filtered through a Whatman no. 540 filter paper, washing the beaker and the filter paper with small portions of deionized water until a volume of about 25 cm^3 was obtained. The filtrate was then transferred to a 50 cm^3 graduated flask and made up to the mark using deionized water [3, 17].

Heavy Metal Analysis

Heavy metal concentrations of the soil and plant samples were determined using Atomic Absorption Spectrophotometer (AAS) at the National Research Institute for Chemical Technology (NARICT), Zaria. The concentrations of the metals determined (Cd, Cu, Fe, Ni, Pb and Zn) were obtained directly from the instrument by aspirating the samples into the instrument. Furthermore, Microsoft Office Excel 2010 and SPSS 15 were used for statistical analysis of the data. Pearson bivariate correlation was used to express the relationship among heavy metals in the vegetable plant.

Enrichment Factor

An element called enrichment factor (*EF*) was initially developed to speculate on the origin of elements in the atmosphere, precipitation, or seawater [18, 19] but it was progressively extended to the study of soils, lake sediments, peat, tailings, and other environmental materials [20]. In this study enrichment factor (EF) was used to assess the level of contamination and the possible anthropogenic impact in Gombe municipal soils. The EF was calculated according to the equation generalized by Zoller et al. [18] as:

$$EF = \frac{(C_i/C_{ie})_S}{(C_i/C_{ie})_{RS}}$$

Where C_i is the content of element i in the sample of interest or the selected reference sample, and C_{ie} is content of immobile element in the sample or the selected reference sample. So $(C_i/C_{ie})_S$ is the heavy metal to immobile element ratio in the samples of interest, and $(C_i/C_{ie})_{RS}$ is the heavy metal to immobile element ratio in the selected reference sample [21]. The selected reference sample is usually an average crust or a local background sample [22-24].

Translocation Factor

To analyze the total metal concentration in dry weight taken by the upper parts of plants (shoots) from ground level, a term called translocation factor (TF) was developed. According to Deng et al. [25] and later Santillan et al. [26], translocation factor is calculated as follows:

$$TF = \frac{Mean\ Shoot\ Concentration\ (mgKg^{-1})}{Mean\ Root\ Concentration\ (mgKg^{-1})}$$

Bioconcentration Factor

Bioconcentration factor (BCF) represents the ratio of metal concentration in the plant to the metal concentration in the soil. It is an indication of the magnification of contaminants from a lower to a higher trophic level. For plants, the BCF has been used as a measure of the metal accumulation efficiency whereby value greater than 1 is an indication of plant's potential to phytoextract or phytoremediate [26-28]. Bioconcentration factor is expressed as:

$$BCF = \frac{Weighted\ Mean\ Plant\ Concentration\ (mgKg^{-1})}{Mean\ Soil\ Concentration\ (mgKg^{-1})}$$

RESULTS

Table 1 summarizes the results of heavy metal concentrations in the soils and plant parts of *Talinum triangulare* at the two waste dumpsites studied and control site. In both the dumpsite soils and plant parts, iron has the highest concentration while cadmium has the least.

Table 1: Heavy metal concentrations (mgKg^{-1}) in dumpsite soils, control soil and plant parts

METAL	DSS$_1$			DSS$_2$			CONTROL		
	Soil	Root	Shoot	Soil	Root	Shoot	Soil	Root	Shoot
Cd	7.10 ±4.01	4.41 ±1.58	5.44 ±2.17	9.76 ±5.22	6.54 ±2.81	8.21 ±3.16	0.35 ±0.10	0.08 ±0.01	0.18 ±0.04
Cu	46.05 ±19.25	32.05 ±8.40	21.30 ±5.01	52.01 ±21.90	41.45 ±16.21	28.00 ±5.87	10.01 ±1.22	5.14 ±1.05	2.50 ±0.08
Fe	814.20 ±119.12	504.00 ±92.18	473.10 ±71.12	853.56 ±123.00	565.01 ±103.14	492.20 ±88.42	710.90 ±21.00	118.25 ±5.01	98.58 ±2.04
Ni	25.63 ±9.08	8.07 ±3.50	6.46 ±1.09	32.81 ±12.40	16.36 ±5.05	12.00 ±4.01	6.45 ±1.01	2.50 ±0.95	1.23 ±0.50
Pb	52.00 ±16.01	20.64 ±4.91	20.26 ±5.12	64.21 ±12.00	25.10 ±2.08	22.08 ±5.11	5.02 ±0.50	2.42 ±0.10	1.50 ±0.25
Zn	165.53 ±64.72	78.02 ±25.10	55.40 ±16.14	201.74 ±84.50	124.50 ±30.44	89.80 ±20.75	21.66 ±2.74	18.00 ±3.55	7.08 ±0.75

DSS$_1$: Bamuza; DSS$_2$: BCGA.

Table 2 gives an assessment categorization of indicators of soil pollution (enrichment factor) and plant heavy metal accumulation (translocation factor and bioconcentration factor). These served as the standard against which the results of this research given in Table 3 were measured to enable reasonable conclusion.

Table 2: Classification of enrichment factor, translocation factor and bioconcentration factor

EF	**Category/Interpretation**	**TF**	**Category/Interpretation**
EF<2	Deficiency to minimal enrichment	TF<1	Low mobility
2≤EF<5	Moderate enrichment	TF≥1	High mobility
5≤EF<20	Significant enrichment	**BCF**	**Category/Interpretation**
20≤EF<40	Very high enrichment	BCF≤1	Non-hyperaccumulator/Non-phytoremediator
EF>40	Extremely high enrichment	BCF>1	Hyperaccumulator/Phytoremediator

Table 3: Enrichment factors, translocation factors and bioconcentration factors of heavy metals in the dumpsites and studied plant

METALS	**ENRICHMENT FACTOR (SOIL)**		**TRANSLOCATION FACTOR (PLANT)**		**BIOCONCENTRATION FACTOR (PLANT)**	
	DSS$_1$	DSS$_2$	DSS$_1$	DSS$_2$	DSS$_1$	DSS$_2$
Cd	17.71	23.23	1.23	1.26	0.69	0.76
Cu	4.02	4.33	0.66	0.68	0.58	0.67
Fe	1.00	1.00	0.94	0.87	0.60	0.62
Ni	3.47	4.24	0.80	0.73	0.28	0.43
Pb	9.04	10.65	0.98	0.88	0.39	0.37
Zn	6.67	7.76	0.71	0.72	0.40	0.53

DSS$_1$: Bamuza; DSS$_2$: BCGA.

Figures 2 and 3 are histograms showing the percentage accumulation of the heavy metals in the various parts (root and shoot) of the studied plant at the dumpsites.

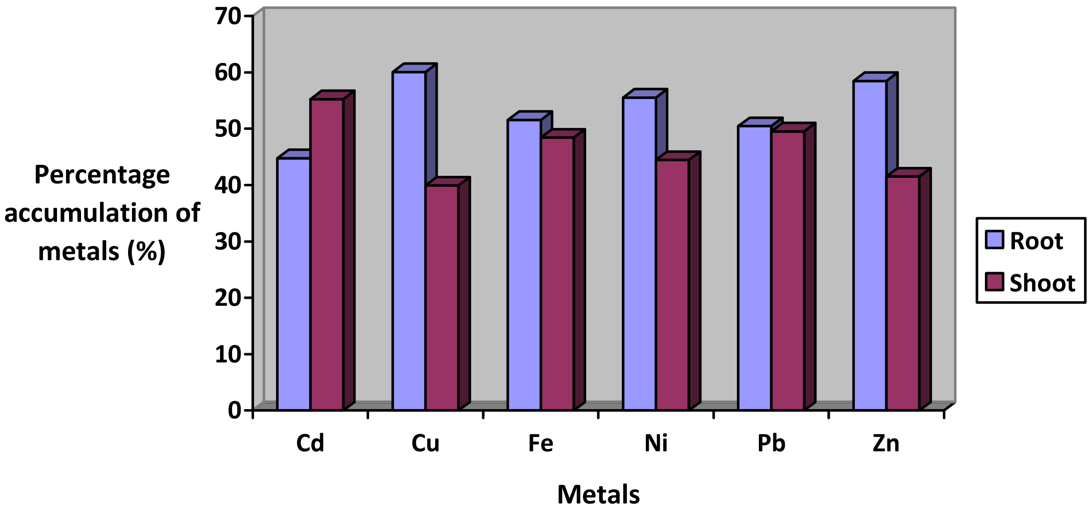

Figure 2: Percentage accumulation of metals by plant parts of *T. triangulare* at DSS_1.

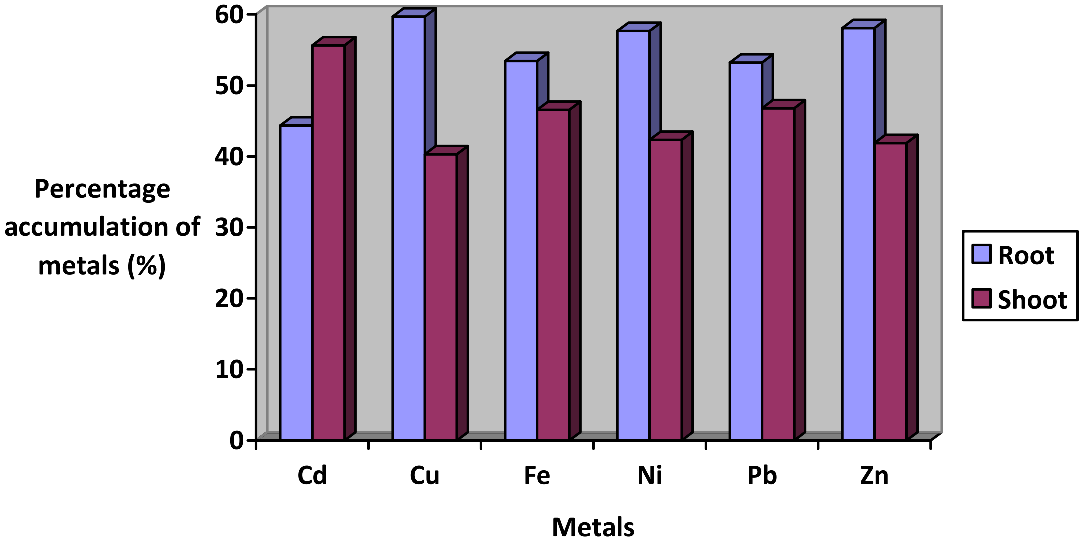

Figure 3: Percentage accumulation of metals by plant parts of *T. triangulare* at DSS_2.

The correlations between the metals in *Talinum triangulare* are shown in Table 4. This Table shows whether there is any relationship existing among the heavy metals in the studied plant.

Table 4: Pearson bivariate correlation coefficient for heavy metals in *Talinum triangulare*

		Cd	Cu	Fe	Ni	Pb	Zn
Cd	Pearson Correlation	1					
Cu	Pearson Correlation	.652(*)	1				
Fe	Pearson Correlation	.415	.353	1			
Ni	Pearson Correlation	.228	.213	.665(*)	1		
Pb	Pearson Correlation	.342	.428	.273	.251	1	
Zn	Pearson Correlation	.534	.806(**)	.194	.326	.425	1

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

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

DISCUSSION

Heavy Metal Concentrations in Dumpsite Soils and Plant

The results in Table 1 shows that the concentrations of heavy metals in the two dumpsite soils and plant studied were well above that of control site. This is an indication that the metal contents of both the dumpsites and plants are related to human activities rather than natural sources. It was also observed that BCGA dumpsite has higher concentrations of all the metals than Bamuza dumpsite. This could be the result of higher commercial and industrial activities associated with the former. The average soil concentrations of the metals in the two dumpsites studied were in the order Fe>Zn>Pb>Cu>Ni>Cd while the order in *Talinum triangulare* was Fe>Zn>Cu>Pb>Ni>Cd. The different levels of these metals in the plant can be explained by their varying concentrations in dumpsite soils. Thus in both the dumpsite soils and studied plant, Fe recorded highest concentrations and Cd the least. In addition, in the two dumpsites studied, it was observed that with the exception of Cd, all metal concentrations in plant parts are in the order: $[M]_{ROOT}>[M]_{SHOOT}$. Thus root system showed higher metal concentrations than the shoot system. This is because the roots are the origin which comes into contact with the heavy metals present in the soil and consequently absorb and accumulate these metals. The concentration of Cd is higher in the shoot than in the root of the plant at both sites. This may be due to atmospheric deposition of the metal from non-ferrous metal activities, fossil fuels combustion, etc. which can be absorbed into foliage and translocated around plant's shoot tissues.

Heavy Metal Enrichment of the Studied Sites

The result of heavy metal enrichment of the dumpsites is presented in Table 3. In this study, the concentrations of the metals at the control (uncontaminated) site were taken as the reference concentrations while Fe was taken as the immobile element. Deely and Fergusson [29] proposed Fe as an acceptable normalization (immobile) element to be used in the calculation of enrichment factor since they considered Fe distribution to be unrelated to other heavy metals. Thus to determine the relative degree of metal contamination, comparisons were made to control concentrations using Fe as the immobile element following the assumption that its content in the crust has not been disturbed by anthropogenic activity. Moreover, it has been chosen as the element of normalization because natural sources (98%) vastly dominate its input [30]. When the results obtained were juxtaposed with categories of enrichment invented by Zoller [18] given in Table 2, the following conclusions could be reached. For Bamuza dumpsite: there is significant enrichment ($5\leq EF<20$) for Cd, Pb and Zn; moderate enrichment ($2\leq EF<5$) for Cu and Ni. For BCGA dumpsite: there is very high enrichment ($20\leq EF<40$) for Cd; significant enrichment ($5\leq EF<20$) for Pb and Zn; moderate enrichment ($2\leq EF<5$) for Cu and Ni. In this study, the enrichment factor of Fe was not considered since its value of 1.00 is expected due to the fact that Fe here served as the immobile element in the equation for calculating enrichment factor. A comparison of the two dumpsites studied revealed that BCGA dumpsite (DSS_2) is more contaminated with the metals than Bamuza dumpsite (DSS_1). Higher commercial and industrial activities associated with the area surrounding the former can be implicated as being responsible. The trend of heavy metal enrichment at both dumpsites is summarized as Cd>Pb>Zn>Cu>Ni. Thus in the two dumpsite soils, Cd has the highest enrichment while Ni has the least.

Heavy Metal Mobility (Translocation) in *Talinum triangulare*

As shown by the result of translocation factors (Table 3), the heavy metals studied were mobile from root to shoot of the plant. The order of mobility of these metals is Cd>Pb>Fe>Ni>Zn>Cu. When compared with the category of mobility given in Table 2, it became obvious that Cd exhibited high mobility (TF>1), followed by Pb, Fe and Ni with relatively high mobility (evidenced by their TF values being close to 1). The high mobility of Cd in *Talinum triangulare* may be due to the fact that Cd can be readily absorbed by plant roots. Studies have also shown that Cd is readily translocated to other plant parts especially the leaves after absorption [31, 32]. On the other hand, Cu and Zn exhibited low mobility from root to shoot of the studied plant. This is in agreement with the fact that the root tissues has the strong capability to hold Cu or Zn against their transport to shoots under conditions of both Cu or Zn deficiency and Cu or Zn excess [33].

Ability of *Talinum triangulare* to Accumulate Heavy Metals on Contaminated Sites

From Table 3, it can be seen that the heavy metal accumulation potential of *Talinum triangulare* varies from metal to metal. As shown by the result of bioconcentration factor, the ability of the plant to accumulate heavy metals in the studied sites observed the following trend: Bamuza dumpsite (DSS_1): Cd>Fe>Cu>Zn>Pb>Ni; BCGA dumpsite (DSS_2): Cd>Cu>Fe>Zn>Ni>Pb. Thus, in the two dumpsites, *Talinum triangulare* exhibited highest bioaccumulation ability for Cd and least for Ni and Pb. The high accumulation of Cd in the plant may be due to the fact that Cd can be readily absorbed by plant roots and easily translocated to other plant parts after absorption [31, 32]. The plant also accumulated Cu, Fe and

Zn at relatively high amount at the two sites. This can be attributed to the three elements being essential for plant growth [31, 34]. This ability of plants to selectively absorb elements essential to its growth has been exploited in phytoremediation technology [1]. In addition, Fe is highly abundant in the earth crust. Although plants are known to accumulate Ni, the low BCF values of Ni in this study (0.28 in DSS_1 and 0.43 in DSS_2) may be attributed to its low enrichment in the dumpsite soils studied. Figures2 and 3 show the percentage accumulation of the metals in the roots and shoots of *Talinum triangulare* at the two sites. It was observed that in the two dumpsites studied, with the exception of Cd, the roots accumulated the metals more than the shoots. This is because the roots are the origin which comes into contact with the heavy metals present in the soil and consequently absorb and accumulate these metals. The higher accumulation of Cd in the shoot than in the root of the plant may be due to atmospheric deposition of the metal from non-ferrous metal activities, fossil fuels combustion, etc. which can be absorbed into foliage and translocated around plant's shoot tissues. In addition, studies have shown that Cd is readily translocated to other plant parts especially the leaves after absorption [31, 32]. A comparison of BCF values obtained in this study with its categorization given in Table 2 reveals that the plant does not exhibit hyperaccumulation properties with regard to the metals studied (Cd, Cu, Fe, Ni, Pb and Zn). However its high bioaccumulation of Cd in the shoot tissues is an indication that it may be risky to consume *Talinum triangulare* grown on dumpsites owing to the toxicity of the metal to humans and animals consuming it.

Pearson Bivariate Correlation Coefficient for Metals in *Talinum triangulare* Plant

Table 4 gives the relationship among heavy metals in *Talinum triangulare.* As can be seen from the Table, a significant positive correlation was observed between total Cd and Cu levels ($p<0.05$) in the whole plant. This can be explained by the fact that both elements are easily absorbed by the plant, Cd being easily transported to the shoots while Cu is greatly retained by the root tissue. The result also revealed significant positive correlations for Cu and Zn ($p<0.01$) and Fe and Ni ($p<0.05$). This is in agreement with previous correlation studies of heavy metals in *Amaranthus hybridus* and *Triticum aestivum* respectively [35, 36]. The metabolic processes of the plant may be responsible since the four elements are essential to plants although they may be toxic beyond a certain threshold.

CONCLUSION

The results obtained revealed that the two dumpsites studied were moderately to very highly enriched with the metals studied especially Cd and Pb. Higher levels of the heavy metals were seen in soils and *Talinum triangulare* of the dumpsites relative to the control site. This clearly implicated anthropogenic activities rather than lithogenic inputs as the sources of these heavy metals. This conclusion was also supported by the fact that the area of high commercial and industrial activities (DSS_2) witnessed higher levels of the metals than the residential or low commercial area (DSS_1). The results also showed that the mobility of the heavy metals (from root to shoot) in *Talinum triangulare* vary from metal to metal with Cd exhibiting greatest mobility and Cu the least among the six heavy metals studied. *Talinum triangulare* was also seen to possess relatively high accumulation potential for Cd, Cu, Fe and Zn but least accumulation for Ni and Pb. With the exception of Cd, the roots accumulated the metals more than the shoots. This is because the roots are the origin which comes into contact with the heavy metals present in the soil and consequently absorb and accumulate these metals. The higher accumulation of Cd in the shoot than in the root of the plant may be due to atmospheric deposition of the metal from non-ferrous metal activities and fossil fuels combustion which can be absorbed into foliage and translocated around plant's shoot tissues, as well as the metal's ability to be readily translocated to plant tops after absorption by the roots. Although this study did not implicate *Talinum triangulare* as a hyperaccumulator plant with regard to the metals studied (Cd, Cu, Fe, Ni, Pb and Zn), its high bioaccumulation of Cd in the shoot tissues is an indication that it may be risky to consume *Talinum triangulare* grown on dumpsites owing to the toxicity of the metal to humans and animals. Thus indiscriminate dumping of refuse and/or cultivation of edible vegetables on dumpsite soils should be discouraged.

COMPETING INTERESTS

Author has declared that no competing interests exist.

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