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EVALUATION OF HEAVY METALS ACCUMULATED IN *AMARANTHUS HYBRIDUS* (L.) GROWN ON CONTAMINATED SOILS IN URBAN KANO, NIGERIA

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Abstract
The present research focused on the phytoextraction potential of *A. hybridus* and assessment of the heavy metals (HMs) accumulated in its various organs. The physicochemical parameters of the soil samples were analysed using Near-Infrared spectrometer (NIRS D-2500) and other standard procedures. The concentrations of HMs in the soil samples and plant organs were analysed using Micro Plasma Atomic Emission Spectrometer (MPA-ES, Model 4210). The degree of HMs contaminants were evaluated using Mueller's Geoaccumulation Index (I_{geo}). Data were statistically analysed using one way Analysis of Variance at $p < 0.05$. The physicochemical analysis results revealed that all the soil samples were sandy-loam in texture and slightly acidic with pH values ranging between 6.11±0.02-5.02±0.06. The concentrations of Organic Matter (OM), Electrical Conductivity (EC), Available Phosphorous (AP), Available Nitrogen (AN), and Cation Exchange Capacity (CEC) vary across the soil samples, with higher OM, CEC and AN revealed in soil site C 3.87±0.14%, 86.04±0.28 cmol/kg and 4.21±0.02% respectively. The results of the HMs analyses across the soils revealed highest concentrations of Fe (311.02 ±0.04 mg/kg), Cu (208.62±0.01 mg/kg) and Zn (112.04±0.04 mg/kg) in soil sample A, Pb (34.03±0.16 mg/kg) and Cr (4.63±0.03mg/kg) were observed to be higher in soil sample C, while the highest concentration of Cd (1.20±0.00 mg/kg) was recorded in soil sample B. Relatively all the concentrations of HMs in the contaminated soil samples were above WHO permissible limit. The findings provide scientific evidence that *A. hybridus* can be used as a tool for environmental management of HMs polluted soil.

Keywords: *Amaranthus hybridus*, Geoaccumulation Index, Contaminated Soils, Phytoextraction.

INTRODUCTION

The presence of heavy metals (HMs) in the environments (air, soil, and water) beyond acceptable limits calls for concern because of the deleterious toxic effects on humans, animals and plants. They are non-degradable by any biological or physical process and are persistent in the soil for a long period, which pose a long-term threat in the environment (Suman *et al*., 2018). HMs such as Pb, Cr, Cd, Hg, As, Cu etc., accumulated in the soils and poses a threat to both plants and animals. Filippelli *et al*., (2010) stated that accumulation in urban environments can be considered very dangerous because of the industrialization and large number of people that can potentially come in contact with it on a daily basis. Although many environmental regulations in developed countries have been enacted to prevent such additional accumulation of dangerous HMs in soil, these metals take a long time before it degrades unlike organic compounds, so removal of such HMs is very necessary (Raymond and Okieimen 2011). The most common methods of exposure to contaminated soil with HMs are through ingestion and inhalation of soil particles, and ingestion of soil particles happens in both children and adults through various activities, consuming contaminated vegetables can also be a cause (Filippelli *et al.*, 2010; Clark *et al.*, 2013).

Different approaches have been employed to remediate HMs contaminated soils, but plants-based technology (phytoextraction) provide a possible alternative, cost effective, ecologically friendly, public accepted than other orthodox physicochemical methods (Burges *et al.*, 2018; Rajput *et al.*, 2019). Phytoextraction which involves the absorption of HMs by plant roots followed by translocation of absorbed metals to shoots and deposition at vacuole, cell wall, cell membrane, and other metabolically inactive parts in plant organs (Arjun *et al.*, 2022). Research on the use of plants to clean HMs contaminated sites has a long history (Xu, *et al.*, 2019; Al-Thani and Yasseen, 2020). The hyperaccumulator plants, known for remedy of HMs, accumulate a higher concentration of HMs in their root and shoot tissues (Arjun *et al.*, 2022). The use of endemic plants species is highly encouraged due to their adaptability to the environment and prevailing climate. Endemic plants vary in their capacity to accumulate or tolerate HMs in their roots and vegetative aerial structures such as leaves and stems. This potential is determined by the level of pollution present in the soil, the physiological features of the species, and their selectivity for HMs (Mandzhieva *et al*., 2016; Tapia *et al*., 2020). Reconnaissance survey to the vegetation growing in polluted sites is an effective approach for identifying plants that may be useful for phytoextraction and or phytoremediation in general (Chapman *et al*., 2019; Monaci *et al*., 2020; Matanzas *et al*., 2021).

Amaranthus Hybridus L. is an annual, short lived perennial plant and cosmopolitan, member of Amaranthaceae family comprising of about 70 species, found both in temperate and tropical regions of the world (Kulczy *et al.*, 2017; Aderibigbe *et al.*, 2022). In Nigeria, the plant has a long history of cultivation. It grows in poor soil condition and is drought-tolerant (Paredes and Hernandez, 1992) *A. hybridus* is known mainly as a vegetable and locally called (Alayahu) in urban Kano. The leaves are a good source of protein and also contribute significantly to calcium and vitamins A and C requirements of humans (Akubugwo *et al.*, 2007, Andini *et al.*, 2013). Scientist reported that production of *A. hybridus* and other species of Amaranthus may help to minimise the malnutrition problem (Jerenimo *et al.*, 2017). Apart from nutritional benefit, evidence from the scientific report in Nigeria showed that dried, ground Amaranthus parts are used to produce local drugs which may be consumed alone or mixed with water or added to local soups, populace of urban Kano are not left behind. The plant has been used traditionally for the treatment of knee pain, liver infections, dysentery, diarrhoea, diuretic, ulcers and hemorrhage of the bowel due to its astringent property (Burkill, 1985; Fernand *et al.*, 2012; Alegbejo, 2013). About 90% of the total intake of heavy metals in humans comes from vegetables, with the remaining 10% coming from dermal contact and breathing in polluted dust (Martorell *et al*., 2011; Khan *et al*., 2015).

The availability of knowledge on plant species capable of extracting HMs in urban Kano is quite limited. Therefore, the goals of the study were (i). To assess the concentration of predominant HMs (Cu, Cd, Cr, Co, Fe, Ni, Pb, As, and Zn) in selected area of urban Kano soils (ii). To employ *A. hybridus* to Phyto--decontaminate the soils. The work plan also includes the analyses of metal(s) accumulation in roots, stem and leaves of the experimental plant using biological indices such as translocation factor (TF) and bioaccumulation factor (BAF).

MATERIALS AND METHODS

Study Area

The research was conducted between January 2019 and December 2021 at Kano metropolis, the capital city of Kano State, Nigeria. Located between latitude 11°59’59.57’’N to 12°02’39.57’’N and longitude 8°31’19.69’’E to 8°33’19.69’’E, with a total urban land area of 137Km^2 and 499Km^2. Kano metropolis is about 481 meters above sea level. It is the most developing and urbanizing city and commercial centre of the Northern Nigeria which encompassed many industries including tannery, textile, chemicals, food, and plastic. The current population (2021) is estimated at 4,103,015. These population estimates and projections come from the latest revision of the UN World Urbanization Prospects. The three (3) specified sites were selected based on the presence of diverse human activities, which involve disposal of industrial waste that may lead to an increase in the amount of toxic metals entering into the environment, and the control site was selected because there was neither human no industrial activities in the area.

Table 1: Sampling Sites and Co-ordinates of the Study Area

	Sampling Sites	Coordinates: Latitude/ Longitude
1	Metals Scraps dumpsite Sharada [A]	11^0 57'49''N $8^0$30'29'' E
2	Stone Crusher (Quarry) site Sauna [B]	$12^0$1'32''N $8^0$35'50'' E
3	Industrial waste dumpsite Sharada [C]	$11^0$57'44''N $8^0$30'44''E
4	Ecological Study Area BUK Control site [D]	$11^0$58'39''N $8^0$28'43''E

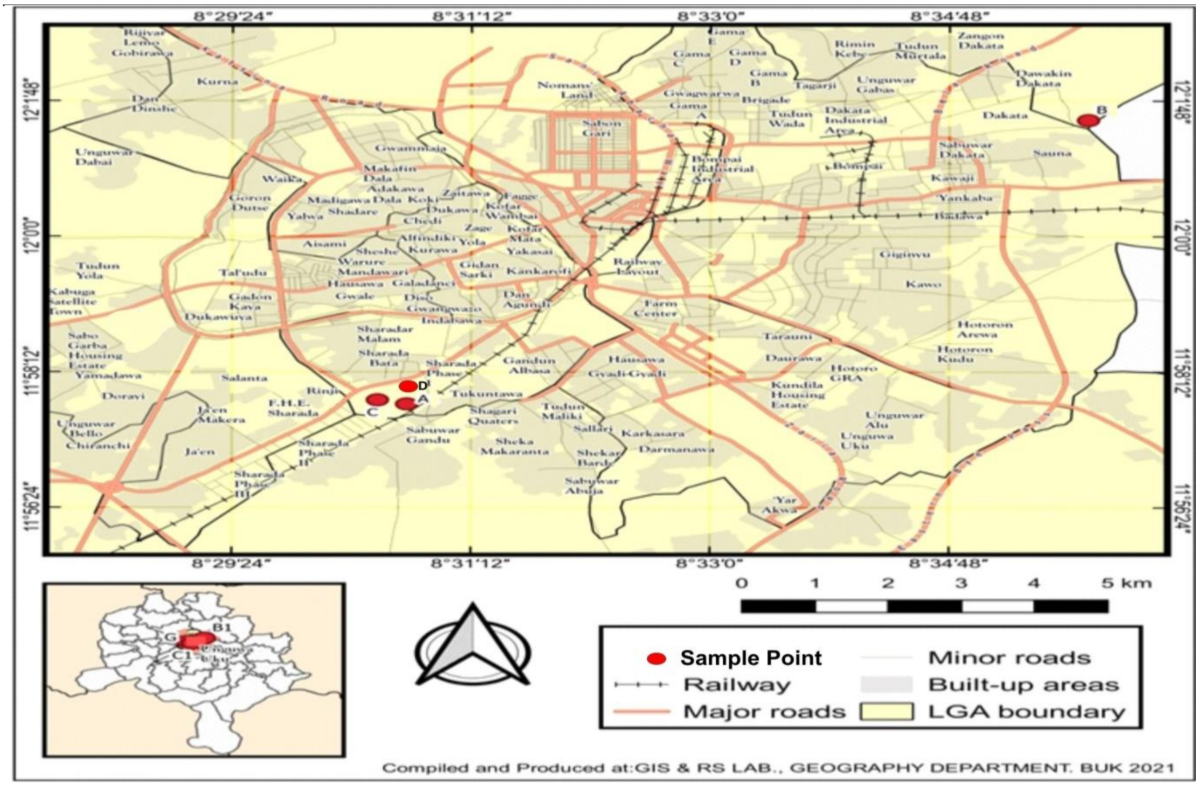

Figure 1: Map of the study area (Kano, Urban) indicating sampling sites. Source: - GIS Lab. Geography Department (BUK, 2021).

Collection of Soil Samples and Processing

According to Qihang *et al*. (2014), and Mumtahina and Sirajul (2021), six points were established, in each sample site 2 m interval each and topsoil (0-15 cm) depth were collected at 3 points (1, 3, and 5) and combined as one samples into polyethene bags and transferred to Bayero University botanical garden for further studies. Using a top loading balance (Model 680, A & D Weighing, US), 45 kg of each contaminated soil sample was measured, 15 kg of the soil sample was also collected from ecological garden Bayero University Kano which served as a control of the experiment. The soil samples were mixed thoroughly after passing through stainless steel sieve (4 mm) to remove non-soil particles such as broken bottles, plastics and stones.

Analyses of Experimental Soil Samples

Near-Infrared Spectrometry (NIRS**)**:

Using Near-Infrared Spectrometer (NIRS D-2500, Metrohm, Switzerland) analyzer, some physicochemical parameters of the soil samples were analyzed. The machine setting was according to manufacturers' instruction and calibration was according to Centre for Dry Land Agriculture (CDA) standard operation procedure. All the parameters were equated with the spectra obtained from the machine library. Other parameters such as pH, available nitrogen and available sulphur are determined using procedure described by (Motsara and Roy, 2008; ASTM, 2017).

Heavy Metals Analyses

The quantitative HMs analyses were carried out using Micro Plasma Atomic Emission Spectrometer (MP-AES: 4210model Agilent, UK). Sample preparation (Using Advanced Microwave Digestion System, Model: EHOS EASY). Nine (9) heavy metals were analysed namely, Arsenic (As), Cadmium (Cd), Cobalt (Co), Chromium (Cr), Copper (Cu), Nickel (Ni), Iron (Fe), Lead (Pb), and Zinc (Zn). The analysis was done at Bayero University Kano Centre for Dryland Agriculture (CDA) laboratory.

Experimental Location

The pot experiment was conducted in the screen house of Plant Biology Department, Bayero University Kano, which lies on latitude $11^0$58'39" N and longitude $8^0$28'44".

Experimental Design

The experiment was laid out in a Completely Randomized Design (CRD). The greenhouse plastic pots with the depth of 19 cm and width of 26.5 cm containing 5 kg of the soil samples were randomly arranged in triplicate, each pot contained four small holes beneath to avoid eutrophication which may leads to unnecessary dying of the research plants.

Research Plant Species

In January 2019, during an established reconnaissance survey to the experimental sites, plant materials (leaves, stems, and seeds) were collected and transferred to BUK, Department of Plant Biology herbarium for identification.

Screen House Condition and Seedling Rising

The temperature and the relative humidity of the screen house were measured using a temperature/humidity meter (CTH 288; Beetech, India). The screen house experiment was commenced in July 2019 with maximum temperature range 33-40.3^{0}C and relative humidity of 55-37%. Fifteen (15) seeds were planted in each pot and after emergence; seedlings were thinned to 8 plantlets per pots. The plantlets were cultivated for 16 weeks (112days) and harvested at inflorescence stage. During the experiment, the plant was irrigated with tap water to maintain soil moisture at a day interval.

Measurement of Growth Parameters

Using different measuring devices, selected growth parameters were observed and measured, such as; Chlorophyll content (chlorophyll meter (CCM 200plus), Plant height (tape cm) and dry weight biomass ((XY300C, Wincom, China).

Experimental Plants Harvest

At sixteen weeks (112days), the plants were carefully uprooted from the experimental soils, the soil particles were removed by shaking and washed with tap water. The roots stem and leaves were separated and were temporarily dried in the screen house before taking to the laboratory hot air oven (DHG 9023, Everich, China) at 60^{0}C for 72hrs, 96hrs and 120hrs for leaves, roots and stem respectively.

Bioaccumulation Factor (BAF)

The value of BAF of metals was used to determine the quantity of HMs absorbed by the plants from the soil. This is an index of the ability of the plant to accumulate a particular metal with respect to its concentration in the soil and is calculated using the formula below: - (Kachenga *et al*., 2020).

$$\text{BAF} = \frac{\textit{Heavy metals concentration in plants } (\frac{mg}{kg})}{\textit{Heavy metals concentration in the soil } (\frac{mg}{kg})}$$

Translocation Factor (TF)

This is an indication of the ability of plants to translocate HMs from the roots to the aerial parts. To evaluate the potential of plants for phytoextraction, the translocation factor was calculated using the formula below (Naz *et al.*, 2022)

$$\text{TF} = \frac{\textit{Heavy metals concentration in stem+leaves } (\frac{mg}{kg})}{\textit{Heavy metals concentration in the root } (\frac{mg}{kg})}$$

Statistical Analyses

The data obtained were subjected to both descriptive and inferential statistics. One-way analysis of variance (ANOVA) was used to compare means, and significantly different means were pairs using Turkey's multiple comparisons to define which specific mean pairs were significantly different with the help of Graphad prism software version 6. The programmed software R. version 4.2.0.was used for the Principal Component Analysis (PCA). All the data presented in figures and tables were expressed as mean ± standard deviation (STD) of three replicates (n=3).

RESULTS AND DISCUSSION

Physicochemical parameters of the soil samples

Table 2 and 3 below revealed the pre and post physicochemical conditions of the experimental soil samples, such as particle size distributions (sand, silt and clay), pH, OM, EC, CEC, Available Phosphorous (Avail. P), and Available Nitrogen (Avail. N). The results of particle size distributions (PSD) of the experimental soil samples defined the textural classes of the soils which is sandy loam deduced from Hirotatsu and Toshiyuki (2015) soil triangle, International Soil Science Society (ISSS) version.

Table 2. The Physicochemical parameters of the experimental soil samples prior to the experiment.

Soil Parameters		**Soil Samples**			
		A	B	C	D (Ctr)
*PSD	Sand (%)	62.12±0.02^{b}	58.22±0.01^{a}	64.18±0.02^{b}	61.21±0.02^{b}
	Silt (%)	16.04±0.01^{b}	24.01±0.01^{c}	11.01±0.01^{a}	18.01±0.01^{b}
	Clay (%)	21.67±0.01^{b}	17.17±0.01^{a}	24.67±0.01^{b}	20.67±0.01^{b}
Soil texture		Sandy loam	Sandy loam	Sandy loam	Sandy loam
pH		5.02±0.06^{a}	5.94±0.03^{a}	5.91±0.08^{a}	6.11±0.02^{a}
Electrical Conductivity (S/m)		12.26±0.41^{c}	4.96±0.23^{b}	12.14±0.16^{c}	2.94±0.12^{a}
Organic Matters (%)		1.05±0.04^{a}	2.70±0.22^{b}	3.87±0.14^{c}	2.96±0.11^{b}
Avail. N (%)		2.11±0.04^{a}	2.31±0.00^{a}	4.21±0.02^{b}	2.10±0.03^{a}
Avail. P(mg/kg)		11.48±0.02^{b}	27.51±0.02^{c}	11.48±0.02^{b}	8.27±0.01^{a}
CEC (cmol/kg)		56.7±0.34^{c}	40.94±0.61^{b}	86.04±0.28^{d}	38.24±0.42^{a}

Key: Values along row with different superscript are significantly different from each other and are mean of three replicates ± standard deviation, using one way analysis of variance (ANOVA) and Turkey's multiple comparisons (P<0.05). PSD= Particle Size Distribution; CEC= Cation Exchange Capacity.

Table 3. Post analyses of physicochemical parameters of experimental soil samples.

Soil Parameters		**Soil Samples**			
		A	B	C	D (Ctr)
*PSD	Sand (%)	71.11±0.02^{b}	68.11±0.00^{a}	74.11±0.01^{b}	68.41±0.00^{a}
	Silt (%)	18.02±0.02^{a}	21.64±0.01^{b}	12.24±0.01^{a}	16.24±0.01^{a}
	Clay (%)	10.67±0.01^{a}	09.67±0.01^{a}	12.67±0.00^{a}	14.67±0.01^{b}
Soil texture		Sandy loam	Sandy loam	Sandy loam	Sandy loam
pH		6.62±0.04^{a}	7.06±0.12^{b}	7.01±0.04^{b}	6.86±0.06^{a}
Electrical Conductivity (S/m)		6.12±0.12^{c}	1.91±0.76^{b}	3.11±0.19^{c}	0.62±0.13^{a}
Organic Matter (%)		0.04±0.41^{a}	0.68±0.05^{b}	0.03±0.00^{a}	0.69±0.01^{b}
Nitrogen (%)		2.12±0.03^{a}	4.91±0.81^{b}	6.11±0.19^{c}	2.62±0.17^{a}
Phosphorus (mg /kg)		6.13±0.31^{b}	10.31±0.00^{c}	6.06±0.29^{b}	6.11±0.00^{a}
CEC (cmol/kg)		20.72±0.67^{b}	16.15±1.01^{b}	59.1±1.25^{d}	14.31±0.68^{a}

Key: Values along row with different superscript are significantly different from each other and are mean of three replicates ± standard deviation, using one way analysis of variance (ANOVA) and Turkey's multiple comparisons (P < 0.05). PSD = Particles Size Distribution; CEC = Cation Exchange Capacity.

The PSD of the experimental soil recorded highest proportions of sand in soil sample C (64.18±0.02%) and the least was recorded (58.22±0.01%) for soil collected from side B. The highest proportion of silt was recorded (24.01± 0.01%) for soil sample B while the least was revealed (11.01±0.01%) for soil sample C. Highest proportion of clay was also revealed in soil sample C (24.67±0.01%) and least was recorded in soil sample B (17.17±0.01). This type of soil (sandy-loam) is regarded as the most suitable for raising plants particularly crop plants in Kano. The soil sample is suitable for the growth of both wild and domesticated plant species. The work of Dawaki *et al*. (2013), Chukwulobe and Saeed (2014) and Olayinka *et al*. (2017), has reported the sandy-loam nature of the study area. Table 2 present the post analysis results, which relativity showed the reduction of all the physicochemical parameters, a clear indication of plants uptake for metabolism and other physiological activities.

The experimental soil pH ranged between 5.02± 0.06 to 6.11± 0.02 which clearly indicates that all the experimental soil samples were slightly acidic as showed in Table 1. The pH ranges obtained in this study were similar to those reported in previous studies (Berefo and Chaney *et al.*, 2014; Audu *et al*., 2016 and Abdulhamid *et al*., 2017). Chukwu *et al*. (2019) reported the similar pH results in 10 different metal scrap sites. pH in the soil plays an important role in the sorption of HMs; it controls the hydrolysis of metal hydroxides and also influences ion-pair formation and solubility of organic matter (Tokalioˇglu, *et al*., 2006). Soil pH is, therefore, described as the "master soil variable" that influences varieties of soil biological, chemical, and physical properties and affects plant growth and biomass yield. (Dora, 2019). The availability of plant nutrients, which might have an impact on how the soil and plants interact with regard to the accumulation of HMs, is also strongly influenced by soil pH (Husson, 2013).

The electric conductivity (EC) of the study soils which is a major indicator of salinity was found to be low, in soil sample collected from site B 4.96±0.23 S/m and D 2.94±0.12 S/m), while higher EC was recorded 12.26±0.41 S/m in soil sample collected from site A. This finding is in line with Sandip *et al*. (2015). In general, EC is used to estimate the soluble salt concentrations in soil and is commonly used as a measure of salinity. Soil with EC below 0.4 S/m are considered marginally or non-saline while soils above 0.8 S/m are considered severely saline (Wagh *et al*., 2013). In post study soils analyses, the values of EC were decreased. The decreased of EC is due to the absorption of some ions including HMs by experimental plants species during metabolisms and other activity for the growth.

The highest percentage of organic matter (OM) was revealed (3.87±0.14%) in experimental soil collected from sample site C and lowest in soil sample site A (1.05±0.04%). Generally, the result of the OM is low compared with organic matter recorded by Olayinka *et al*. (2017) and Ogbodo *et al*, (2019) both the authors characterized the physicochemical property of soil samples obtained from selected anthropogenic areas in Abeokuta and Markurdi, Nigeria. The low level of organic matter from both contaminated soils attributed to sandy texture of soils. The physical, chemical, and biological properties of soil are significantly influenced by soil organic matter. Specifically for sandy soils that can control heat absorption and release, soil organic matter can improve soil permeability, raise soil resistance to erosion, increase water holding capacity, and play a role in delivering moisture (Wibowo and Kasno 2021). Biologically, soil organic matter contributes to the active character of soil colloids and their physiological functions as a growth hormone (Wibowo and Kasno 2021). While chemically, soil organic matter provides a source of nutrients for plants.

The result of the available nitrogen across studied soil samples was also low ranging between 2.11±0.04 - 4.21±0.02 mg/kg with the highest showed in experimental soil sample collected from site C and the least in soil sample collected from site A. The values of nitrogen reported in this study is high while compared with low nitrogen content reported by Abdulhamid *et al*. (2017) on industrially contaminated dump site soil and also Dawaki *et al*. (2013) reported similar results of low nitrogen in Kano Urban Agricultural Lands.

Phosphorus content of the experimental soil samples were recorded higher in soil sample collected from site B (27.51±0.02 mg/kg) due to the facts that phosphorus is one of the major components of rocks Porder *et al.*, (2013), and soil sample site D has showed the least content of phosphorus (8.27±0.01 mg/kg). Wunzani *et al*. (2020) reported similar soil phosphorus content in some selected solid waste dumpsite. After nitrogen, phosphorus ranks as the second-most crucial nutrient for crops. In all metabolic processes, including photosynthesis, respiration, energy storage, transfer, cell division, cell enlargement, and nitrogen fixation, it is a crucial macronutrient (Esther, 2019).

Regarding Cation Exchange Capacity (CEC), soil sample collected from site C revealed the highest value of CEC (86.04±0.28 cmol/kg), while the least CEC was recorded in experimental soil collected from site D (38.24±0.42 cmol/kg). In soil post experiment reduction of CEC was recorded in all the soil samples which indicate the uptakes of ion by the experimental plants species. Soils that have higher CEC are considered to be more fertile than soils with low CEC, since is an important measure of the soil's ability to retain and to supply nutrients (Wodaje and Alemayehu, 2017).

The post analyses result of soil samples physicochemical parameters presented in Table 3, revealed the textural characteristics of the soil remained sandy loam with little reduction of some values. The pH values of soil samples collected from site A and D remained slightly acidic ranged between 6.62±0.04 and 6.86±0.06 whereas the pH of soil sample collected from site B and C changed from acidic to neutral 7.06±0.12, 7.01±0.04 respectively. There was reduction of some values in other parameters such as OM, EC, Avail. N and Avail. P in post analyses across sites as presented in Table 2, which proved evidence of biological activity of the experimental plant species.

Heavy Metals Concentrations in Soil samples

The mean concentration of each HM in soil samples before and after the experiments was presented in Table 4. The means concentrations result varies across experimental soils and virtually all the concentration of HMs across the experimental soils are above WHO/FAO set standard limits of HMs in soil.

Table 4. Mean Values of Heavy Metals Concentrations (mg/kg) of Study Soil Samples Before and After the Experiments

	Heavy Metals								
Sample Sites	Zn	Cd	Cu	Ni	As	Co	Pb	Fe	Cr
Before Experiments									
CSA	112.04±0.04^{d}	0.06±0.04^{a}	208.62±0.01^{d}	0.09±0.05^{a}	0.32±0.21^{b}	0.05±0.00^{a}	4.18±0.01^{b}	311.02±0.04^{d}	0.53±0.11^{b}
CSB	6.34±0.61^{b}	0.01±0.00^{a}	20.02±0.10^{c}	0.01±0.08^{a}	0.34±0.11^{b}	0.04±0.00^{a}	0.07±0.03^{a}	28.14±0.61^{c}	0.56±0.12^{b}
CSC	50.14±0.16^{c}	1.20±0.00^{b}	20.14±0.06^{c}	0.01±0.05^{a}	0.24±0.02^{b}	0.03±0.00^{a}	43.77±0.01^{c}	34.03±0.16^{c}	4.63±0.02^{c}
SSD	6.10±0.13^{b}	0.01±0.00^{a}	3.28±0.03^{b}	0.04±0.00^{a}	0.35±0.03^{b}	0.03±0.00^{a}	0.01±0.00^{a}	16.06±0.13^{b}	0.13±0.04^{b}
After Experiments									
CSA	33.01±0.06^{d}	0.01±0.00^{a}	12.21±0.01^{c}	0.03±0.01^{a}	0.17±0.01^{b}	0.05±0.00^{a}	0.06±0.01^{a}	42.21±0.01^{c}	0.13±0.00^{b}
CSB	0.04±0.21^{a}	0.01±0.00^{a}	4.02±0.10^{b}	0.01±0.13^{a}	0.06±0.01^{a}	0.04±0.00^{a}	ND	10.02±0.10^{b}	0.11±0.10^{b}
CSC	11.0±0.01^{c}	0.01±0.00^{a}	0.02±0.01^{a}	0.01±0.05^{a}	0.08±0.02^{a}	0.03±0.00^{a}	8.03±0.00^{b}	6.12±0.01^{a}	0.21±0.01^{b}
SSD	0.16±0.02^{b}	ND	0.12±0.03^{a}	0.01±0.00^{a}	0.06±0.03^{a}	0.01±0.00^{a}	ND	2.09±0.03^{a}	ND
WHO (2016)	3.00	0.003	1.00	0.05	1.00	1.3	0.1	0.02	0.1

Key: Values are means of three replicates ± standard deviation, all values along a particular column with different superscripts are statistically not significant from each other. Using one way analysis of variance (ANOVA) and pairs using Turkey's multiple comparisons ($P < 0.05$).

CSA= Contaminated Soil [A] Metal scrap dump site Sharada; CSB=Contaminated Soil [B] Stone crusher (quarry) Sauna; CSC=Contaminated Soil [C] Industrial waste dump site Sharada; SSD= Soil Sample [D] control (ecological study area Bayero University Kano); ND= Not Detected; WHO= World Health Organization.

Concentration of Iron (Fe) in the studied soil samples: Fe proved highest concentrations across the studied soil samples which defined the ferruginous nature of Kano urban soil. The highest mean concentration of Fe was recorded 311.02±0.04 mg/kg in soil sample A, and least concentrations were obtained in soil collected from side D 16.06±0.13 mg/kg. The high level of iron might be due to the fact that most of the scraps objects in the dumpsite are made up of Iron or Iron materials. Iron also ranking fourth most abundant element in the earth's crust (Wodaje and Alemayahu, 2017).

Concentration of Zinc (Zn) in the studied soil samples: The mean concentration of Zn varied across the four studied samples with the highest value recorded in soil sample collected from site A 112.04±0.04 mg/kg while the least was recorded 6.34±0.61mg/kg in soil sample collected from site B. Both the mean concentrations level of Zn from the three locations was higher than the control site D 6.10±0.13 mg/kg. All the concentrations of Zn from the studied soil sites are higher than USEPA, 2000 and WHO, 2016 permissible limit of 2.0 and 3.00 respectively. The abundance of Zn in dump site was reported by Tariwari *et al*. (2016) and Wunzami *et al*. (2020).

Concentration of Cadmium (Cd) in the studied soil samples: The concentration of Cd in the studied soils was presented in Table 4. The level of Cd ranged from 0.01±0.00-1.20±0.00 mg/kg. This clearly showed that the concentrations of cadmium across the experimental sampling sites were low but higher than WHO permissible limit of Cd on both water and soils for agriculture 0.003 mg/ml (Aneyo *et al.*, 2016). The highest concentrations of Cd were recorded in soil sample collected from site A 1.20±0.00 mg/kg. Akpoveta *et al.* (2010) reported similar result of Cd in soils around metal scraps dump site. Ogbodo *et al*. (2019) and Usman *et al*. (2020) also recorded the presence and higher concentrations of Cd above WHO permissible limit in contaminated soil.

Concentration Copper (Cu) in the studied soil samples: The mean concentrations of Cu in the study soil collected from sites A, B and C are higher than that of D (control) sample and also higher than WHO permissible limit (1.000 mg/kg), soil sample collected from site A reveals highest level of Cu 208.62±0.01 mg/kg and the least was recorded from experimental soil collected from site B 20.02±0.10 mg/kg. The value was high than that of soil collected from control site 3.28±0.03 mg/kg. This result is in agree with the finding of Rinklebe *et al*. (2012), Abdulhamid *et al*. (2017) and Ogbodo *et al*. (2019) both with the aim of decontaminating industrial and other waste dump site soils contaminated with HMs. The higher concentrations of Cu in both the studied sites were linked with the communal used of materials made up of Cu.

Concentration Nickel (Ni) in the studied soil samples: The means concentrations of Ni ranged between 0.01±0.05 to 0.09±0.05 mg/kg in both soil samples collected from site C and A respectively. Across the study sites only soil sample collected from site A recorded mean value above permissible limits 0.09±0.05 mg/kg. The recommended safe limits by WHO for Ni in water and agricultural soils are 0.02 and 0.05ppm respectively (Aneyo *et al*., 2016). The low concentration of Ni in contaminated soil was also reported by Akpoveta *et al*. (2010), while in contrast Rinklebe *et al*. (2012) reported the high concentrations of Ni in contaminated soil. The fluctuation of Ni concentration in various contaminated soil sites has a linked with the ages and the types of wastes. Nickel occurs in the environment at very low levels and the natural sources of atmospheric nickel are dust, volcanic emissions and the weathering of soils (Ambika *et al*., 2016; Al-lami *et al*., 2020).

Concentration of Arsenic (As) in the studied soil samples: The highest level of As was recorded in the soil sample collected from site B 0.35±0.03 mg/kg which may likely be as a result of stones dust, and the least was recorded in soil sample collected from site C 0.24±0.02 mg/kg as showed in Table 4. These results were in agree with the findings of Agbeshiea *et al*. (2020) who recorded a low level of As in municipal waste dumpsite. Arsenic is gotten naturally and artificially as a result of weathered volcanic rocks, fossil fuels, agricultural chemicals, wood preservatives, medicinal products and industrial activities (Garelick *et al*., 2008).

Concentration Cobalt (Co) in the studied soil samples: **Co** was recorded low across the soil sample sites, the highest concentration was recorded in experimental soil collected from site A (0.07±0.00 mg/kg) and the least was recorded from contaminated soil collected from site C 0.03±0.00 mg/kg. The post analysis results in Table 4 revealed 0.05±0.00 mg/kg that indicates slightly accumulation of Co by experimental plants species. These finding is in line with Solomon (2019) that recorded low Cobalt concentration in soil collected from different waste dump sites. Cobalt found naturally in the earth's crust.

Concentration of Lead (Pb) in the studied soil samples: The concentration of Pb in all the experimental soil samples varies and higher than WHO, permissible limits (0.1mg/kg). The highest concentrations were recorded 43.77±0.01 mg/kg in soil sample C while the least 0.07±0.03 mg/kg was recorded in soil sample B. Pb was not detected in the control soil sample. In soil sample C, the HMs concentration values decreased from 43.77±0.01 mg/kg to 8.03±0.00, showing that the plant species had the ability to extract and transfer Pb to various organs, see Table 4. The result of high level of Pb in dump sites is in agree with the finding of Chukulobe and Saeed (2014), Karkarna, and Mujahid (2020) also recorded high level of Pb and other HMs in some dumpsites of Kano metropolis. Low level of Lead in quarry contaminated soil was also reported by Tiimub *et al*., (2015). The Pb notable sources in the environment are petroleum, electronic industries, battery; lead based paint, stained glass household dust and biocide preparation (Muhammad *et al*., 2020; Ekeleme *et al*., 2021). Lead can accumulate in the human body and may cause various health ailments. There has been a lot of attention paid to Pb levels in soil because it is well-known to cause adverse health effects, and is relatively widespread as a result of its historical use in many commercial products, from gasoline to paint (Mofor *et al*., 2017) It can enter the human body through uptake of food (65%), water (20%) and air (15%) (Ruqia *et al*., 2015).

Concentration Chromium (Cr) in the studied soil samples: The highest level of Cr was revealed in soil sample site C (4.63±0.02 mg/kg) while the lowest was recorded in soil sample site A (0.53±0.11 mg/kg) as shown in Table 4, all the values are above WHO (2016), permissible limit. The concentration of Cr on studied soil site A, B, and C was higher than that of control soil sample 0.13±0.01 mg/kg. The results of high level of Cr in contaminated soils were in agreement with the findings of Abdulhamid *et al*. (2017), Solomon (2019) and that of Vasileios *et al*. (2021) while Karkarna and Mujahid (2020) recorded the low concentration of Cr in different dumpsites soil within Kano metropolis. Chromium is known to be a toxic metal that can cause severe damage to both plants and animals (WHO, 2000; Ambika *et al*., 2016).

Geoaccumulation Index

HMs geoaccumulation in the studied soil sample (A) shows heavily to extreme contamination with Zn, Fe, Pb, and Cu while Cd proof moderate to heavily contamination. Studied soil from site (B), however, exhibit various levels of geoaccumulation class, Ni showed strong contamination while Cu, Pb and Cr showed moderate to heavily contamination. Studied soil collected from site (C) proved extreme contamination with Pb, Cd and Cr mean while strong to moderately contaminated with Ni, Cu and Zn as presented in Table 4. Generally, the Igeo status of the soil samples was firmly proof both the natural and anthropogenic sources of the contaminants. The negative values indicate the sources of HMs contaminants are not anthropogenic.

Table 4. The Igeo Class of studied HMs deduced from 0 -6 Muller Geoaccumulation Index

HMs	Site A	Site B	Site C
Zn	3.61	-0.53	2.45
Cd	2.00	-0.58	6.32
Cu	5.41	2.02	2.03
Ni	0.58	-2.58	-2.58
As	-0.71	-0.63	-1.13
Co	0.15	-0.17	-0.58
Pb	8.12	-2.22	11.51
Fe	3.69	0.22	0.49
Cr	1.42	1.52	4.57

I_{geo} class and level of contamination	
Igeo≤0	*Uncontaminated*
0<Ieo<1	*Uncontaminated to moderately contaminated*
1<Igeo<2	*Moderately contaminated*
2<Igeo<3	*Moderately to Heavily contaminated*
3<Igeo<4	*Strongly contaminated*
4<Igeo<5	*Heavily to extremely contaminated*
5< Igeo≥6	*Extremely contaminated*

I_{geo} Class: Adopted from Mueller (1969).

Heavy Metals Accumulated in the experimental Plants Organs

The mean concentration results of accumulated HMs in various parts of the experimental plants species were presented in Tables 6-9. HMs accumulated in plants organs exhibited profound variation in response to concentration in the soil samples. In soil sample site A., *A. hybridus* proved the highest capacity of accumulating Fe, Cu, and Zn in the following increasing order 108.21±0.54 > 64.82±0.45 > 36.1±0.54, for roots, stem, and leaves respectively. The results followed the similar pattern in all the studied soil samples. Generally, the findings reveal the potentials of *A. hybridus* to accumulates essential HMs (Fe, Cu, and Zn) in its harvestable organs while the nonessential HMs such as (Pb, Cd, Cr, As, and Co) are accumulated more in roots, whereas the essential and nonessential can also be accumulated in the stem, see Table 6-9. Accumulation of HMs in various organs by *A. hybridus* is an indication of plant potential for phytoextraction which defined an evidence of HMs translocation through root uptake, this finding is supported by the work of (Briaget *et al*., 2019).

Table 6. Mean Values of HMs Concentration (mg/kg) accumulated in Different Parts of *A. hybridus* grown on Soil Sample Site A.

Heavy Metals	**Plant Organs**			**Total**
	Roots	**Stem**	**Leaves**	
Zn	$24.73{\pm}0.60^{b}$	$14.63{\pm}0.01^{a}$	$36.1{\pm}0.54^{c}$	$\mathbf{75.46{\pm}1.15^{d}}$
Cd	$0.03{\pm}0.01^{a}$	$0.02{\pm}0.01^{a}$	ND	$\mathbf{0.05{\pm}0.02^{a}}$
Cu	$34.03{\pm}0.02^{b}$	$22.61{\pm}0.01^{a}$	$64.82{\pm}0.45^{c}$	$\mathbf{121.46{\pm}0.48^{d}}$
Ni	$0.02{\pm}0.00^{a}$	$0.01{\pm}0.01^{a}$	$0.02{\pm}0.01^{a}$	$\mathbf{0.05{\pm}0.02^{a}}$
As	$0.06{\pm}0.01^{a}$	$0.02{\pm}0.01^{a}$	ND	$\mathbf{0.08{\pm}0.02^{a}}$
Co	$0.03{\pm}0.01^{a}$	$0.01{\pm}0.00^{a}$	ND	$\mathbf{0.04{\pm}0.01^{a}}$
Pb	$2.04{\pm}0.02^{c}$	$0.01{\pm}0.00^{a}$	ND	$\mathbf{2.04{\pm}0.02^{b}}$
Fe	$68.33{\pm}0.60^{a}$	$82.73{\pm}0.01^{b}$	$108.21{\pm}0.54^{c}$	$\mathbf{259.27{\pm}1.15^{d}}$
Cr	$0.35{\pm}0.01^{a}$	ND	ND	$\mathbf{0.35{\pm}0.01^{a}}$

Key: All values along row with different superscript are significantly different from each other using one way ANOVA and pairs using Tukey's multiple comparisons (P<0.05). **HMs**: Heavy Metals; ND: Not Detected.

Table 7. Mean Values of HMs Concentration (mg/kg) accumulated in Different Parts of *A. hybridus* grown on Soil Sample Site B.

Heavy Metals	**Plant Organs**			**Total**
	Roots	**Stem**	**Leaves**	
Zn	$1.08{\pm}0.61^{a}$	$1.37{\pm}0.05^{a}$	$2.85{\pm}0.04^{b}$	$\mathbf{5.03{\pm}0.70^{c}}$
Cu	$5.22{\pm}1.44^{b}$	$1.60{\pm}0.26^{a}$	$10.76{\pm}0.81^{c}$	$\mathbf{17.58{\pm}2.51^{d}}$
Ni	ND	ND	ND	ND
As	$0.08{\pm}0.12^{a}$	$0.10{\pm}0.03^{a}$	$0.14{\pm}0.16^{a}$	$\mathbf{0.32{\pm}0.31^{a}}$
Pb	ND	$0.02{\pm}0.02^{a}$	ND	$\mathbf{0.02{\pm}0.02^{a}}$
Cr	$0.45{\pm}0.15^{a}$	$0.05{\pm}0.02^{a}$	ND	$\mathbf{0.50{\pm}0.17^{a}}$
Fe	$6.08{\pm}0.61^{a}$	$9.17{\pm}0.05^{b}$	$11.25{\pm}0.04^{c}$	$\mathbf{26.25{\pm}0.70^{d}}$

Key: All values along row with different superscript are significantly different from each other using one way ANOVA; and pairs using Tukey's multiple comparisons (P<0.05). **HMs**: Heavy Metals; **ND**: Not Detected.

Table 8. Mean Values of HMs Concentration (mg/kg) accumulated in Different Parts of *A. hybridus* grown on Soil Sample Site C.

Heavy	**Plant Organs**	**Total**

Metals	Roots	Stem	Leaves	
Zn	9.57±1.35^{a}	23.77±0.20^{c}	12.45±0.54^{b}	**45.79±2.09^{d}**
Cd	0.06±0.01^{a}	0.03±0.01^{a}	ND	**0.09±0.02^{a}**
Cu	4.61±1.06^{a}	6.27±0.09^{b}	7.62±1.74^{b}	**18.50±2.89^{c}**
As	0.13±0.18^{a}	0.05±0.03^{a}	ND	**0.18±0.21^{a}**
Pb	15.10±0.92^{c}	12.62±0.11^{b}	9.54±0.03^{a}	**37.26±1.06^{d}**
Cr	2.43±0.03^{a}	1.66±0.21^{a}	ND	**4.09±0.24^{b}**
Fe	5.80±0.61^{a}	11.13±0.05^{b}	16.06±0.04^{c}	**32.27±0.70^{d}**

Key: All values along row with different superscript are significantly different from each other using one way ANOVA and pairs using Tukey's multiple comparisons ($P<0.05$). **HMs**: Heavy Metals **ND**: Not Detected.

Table 9. Mean Values of HMs Concentration (mg/kg) accumulated in Different Parts of *A. hybridus* grown on Soil Sample Site D.

	Plant Organs			
Heavy Metals	**Roots**	**Stem**	**Leaves**	**Total**
Zn	1.75±0.34^{a}	0.77±0.08^{a}	2.28±0.18^{b}	**4.80±0.60^{c}**
Cu	0.51±0.03^{a}	0.41±0.05^{a}	1.57±0.01^{a}	**2.49±0.09^{b}**
Ni	ND	ND	ND	ND
As	0.13±0.29^{a}	0.04±0.03^{a}	0.08±0.35^{a}	**0.25±0.67^{a}**
Fe	3.38±0.61^{a}	3.08±0.05^{a}	7.15±0.04^{b}	**13.61±0.70^{c}**
Cr	0.07±0.00^{a}	0.02±0.01^{a}	0.02±0.01^{a}	**0.11±0.02^{a}**

Key: All values along row with different superscript are significantly different from each other using one way ANOVA and pairs using Tukey's multiple comparisons ($P<0.05$). **HMs**: Heavy Metals; **ND**: Not Detected

Bioaccumulation and Translocation Factor

The bioaccumulation factor represents the ability of *A. hybridus* to extract heavy metals from the soils was presented in Table 10. Based on the concentration of HMs in the studied soils *A. hybridus* showed highest bioaccumulation of Fe, Zn, and Cu which ranged between 0.84 – 0.95, 0.69-0.91, and 0.58- 0.92 respectively. Research evidence suggested that BAF values of zero indicate limited movement of the HMs from the soil to the plant. The TF save as tool of assessing the plant potential for phytoextraction, it indicates the ability of plant to transport metal from the roots to shoot. A TF value greater than 1 is indicative of metal accumulation and transport into the different plant parts, and less than 1 is suggestive of storage of metal in roots. TF value larger than 1 indicates that metal is accumulated and transported into the various plant components, whereas a value less than 1 indicates that metal is stored in the roots. (Devi *et al*., 2012). Relatively all the studied HMs with exception of Cr, Co, and Ni, has the TF values above unity in *A. hybridus*, indicative of translocation and storage in aerial parts, and higher values correspond to a greater transfer see Figure 2.

Table 10. Bioaccumulation Factor (BAF) of studied HMs in *A. hybridus* species Grown across Soil samples.

Soil Sampling Sites	**Heavy Metals**								
	Zn	**Cd**	**Cu**	**Ni**	**As**	**Co**	**Fe**	**Pb**	**Cr**
A	0.67	0.83	0.58	0.56	0.25	0.80	0.88	0.64	0.66
B	0.79	0.00	0.88	0.00	0.94	0.00	0.94	0.71	0.89
C	0.91	0.75	0.92	0.00	0.75	0.00	0.95	0.85	0.88
D (control)	0.79	0.00	0.76	0.00	0.71	0.00	0.84	0.00	0.85

Value above unity indicates high potentials for phytoextraction by a plant species.

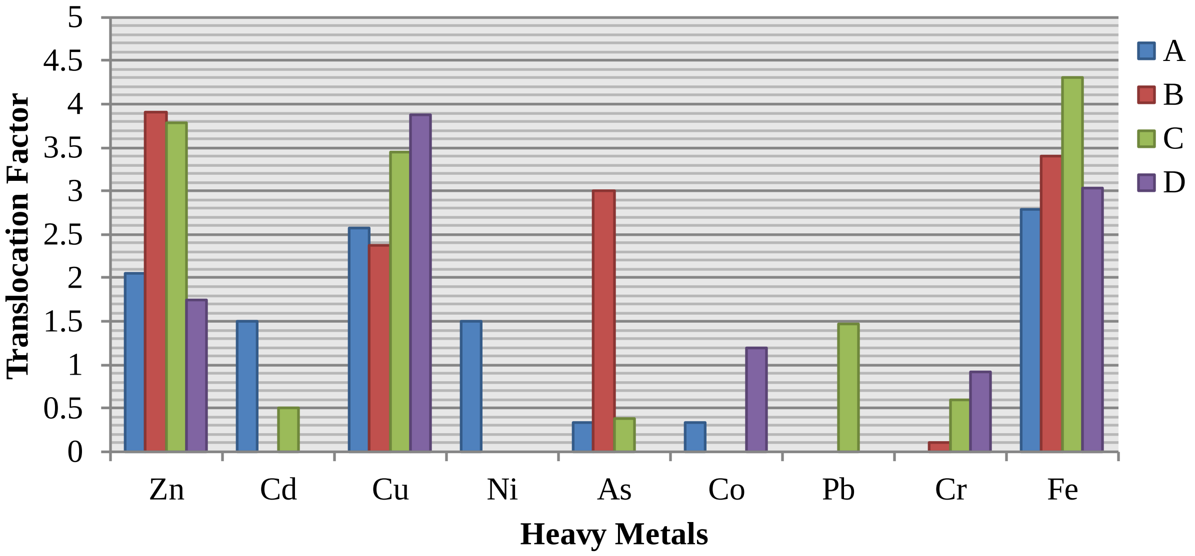

Figure 2. The TF of studied HMs in Experimental Plant species Grown across studied Soil Samples.

The observation of *A. hybridus* height across studied soils for the period of 13th weeks was presented in figure 3. At initial stage from 1st -3rd weeks no height difference was observed *A. hybridus* followed the same growth patterns across the study soil samples see Figure 3. At 13 weeks, the height was recorded in the following increasing order 103 > 80.3 > 76 >52 cm for the plant grown on soil collected from site C, D, B, and A respectively, as presented in Figure 3. Despite the duration of his work, Adekiya *et al*. (2019) reported similar growing patterns (98 cm) height of *A. hybridus* grown on contaminated soil amended with poultry manure.

The Chlorophyll is a main material for photosynthesis, founds in plants that gives them their green colour and it also enables them to absorb the light for photosynthesis. The contents of chlorophyll reflect leaf photosynthesis ability and plant health condition (Li *et al*., 2018). The chlorophyll production of the experimental plant followed the same pattern of decreasing with the plant height 42.96 < 39.67 < 36.13 < 12.54 μg/mm for soil sample C, D, B, and A respectively. This observation agreed with Orhue 2005; Bridget *et al*., 2018). The total plant dried biomass (roots, stems and leaves) were presented in Figure 5. The maximum weight of dried biomass was recorded in the following increasing order 363.67 > 321.11 > 196.44 > 69.03 from plant grown on soil sample C, B, D, and A respectively.

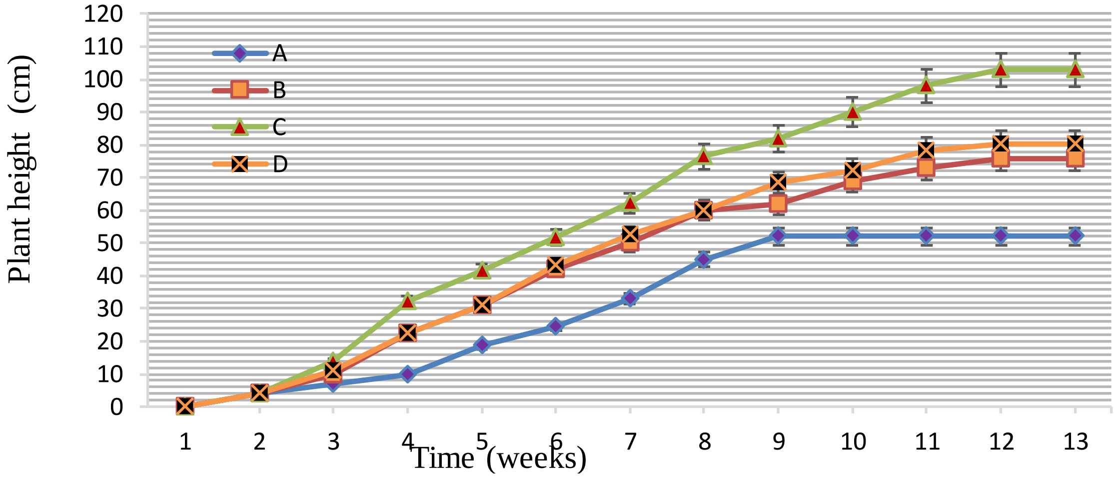

Figure 3: Weekly Height (cm) of *A. hybridus* Across the Experimental Soil Samples for 13 Weeks.

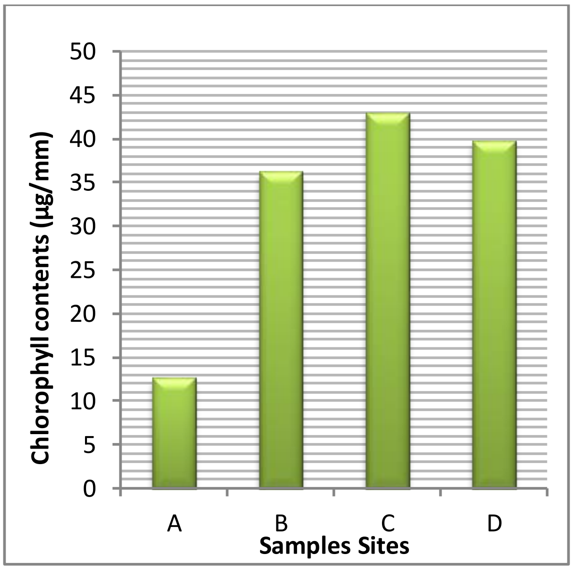

Figure 4: Mean Values of Chorophyll Content (µg/mm) in *A. hybridus* Species across Soil Samples.

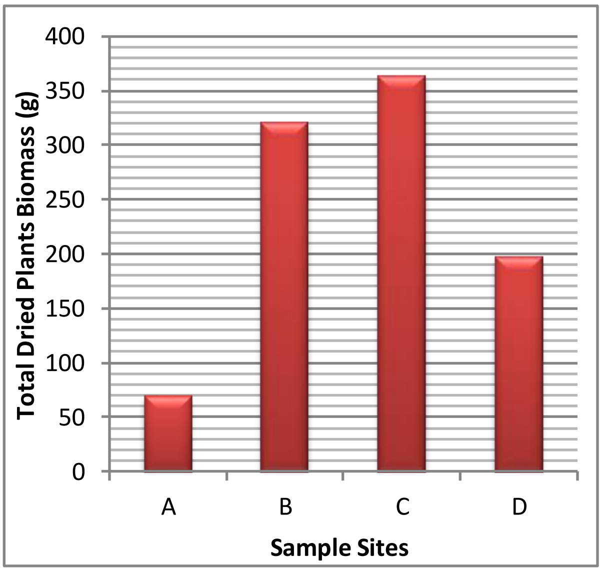

Figure 5: Total Plants dried biomass (g) of _A Hybridus grown across the study soil sites

Principal Component Analysis (PCA)

The overall performance of *A. hybridus* in terms of accumulation of multiple metals was subjected to biplot Principal component analysis**,** reduction of multidimensional variables. Based on the analysis, *A. hybridus* proof that the first two components were responsible for 76.6% of the total variation. Specifically, the response data obtained for the parts of species *A. hybridus* collected from the four locations (A-D) revealed that Fe, As, and Cd were the major contributors to the variance of the first and second primary dimensions (components). The presence of the HMs Fe, Cu, Ni, Co, and Zn had a positive correlation with all the parts of the species investigated in location A but had a negative relationship with As, Pb, Cr, and Cd. For location C, only the stem and root had a positive correlation with Pb, Cr, and Cd. The plant parts, however, had a negative correlation with Fe, Cu, Ni, Co, Zn, and As. The leaf of the species in location C had no link with increased amounts of any of the HMs. Except for As, all heavy metals demonstrated a negative correlation with all plant parts collected from locations B and D.

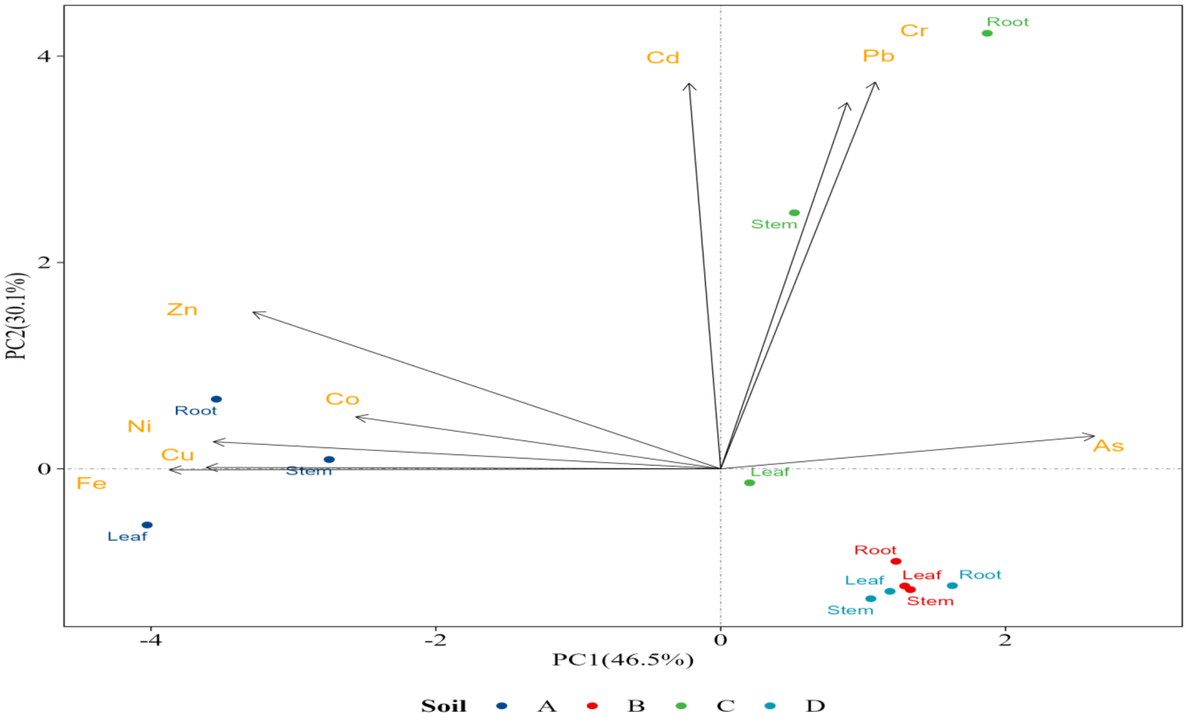

Figure 6. Principal Component Analysis (PCA), a biplot showing reduction of multidimensional variables of means concentrations of HMs in *A. hybridus* organs grown across experimental soil samples.

CONCLUSION

Contamination of soil with HMs in the environment of urban Kano is a serious public health concern. The Igeo accumulation index defined various degree of contamination, form moderate to extreme pollution at various studied sites. All the three (3) contaminated soils including the control are sandy loam in texture based on particle sizes distribution and slight acidity ranging between 6.11±0.02-5.02±0.06, the mean values of EC, Avail N, Avail, P, CEC as well as the mean HMs concentration values of the studied metals in the studied soils (Fe, Cu, Zn, Pb, Cr, Cd, As, Co and Ni) were relatively higher than the control, and standard regulatory limits set by WHO. The experimental plant growth response indicates that the plant species grown on soil sample collected from site C proved maximum height, chlorophyll content, and biomass production. The bioaccumulation and translocation factor above unity of HMs evaluated from *A. hybridus* organs proved its potential accumulation of certain HMs. The findings revealed that the experimental plant species is promising; can be employed for phytoextraction, therefore can be used as well as effective tool for HMs polluted soil management. Meanwhile, from the toxicological, and health points of view *A. hybridus* should not be used as food or medicine when grown in polluted area.

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