Accumulation and Translocation of Toxic Elements From Contaminated Soils, Nigeria: Implications for Phytomining and Hazards to Humans

Eneojo G Ameh (ehiwill@gmail.com)
Federal University, Gusau
Samuel M Kolawole
Federal University Oye-Ekiti
Sunday O Idakwo
Ibrahim Badamosi University, Lapai
Ile O Ojonimi
University of Jos

Research Article

Keywords: Accumulation, Translocation; Hazards, Native plants, Ores, Phytomining

Posted Date: February 19th, 2021

DOI: https://doi.org/10.21203/rs.3.rs-238390/v1

Abstract

Soil pollution by heavy metals and their health effect on human are pressing issues of the environment caused by human activities. Plant's accumulation and translocation potentials were investigated to determine their suitability for phytoremedial purposes, their ability to serve as reservoir for recovery of additional economic amount of metals and the potential of the edibles/vegetables to cause harm to humans when consumed. The plant and soil samples were collected, prepared, digested in acid mixture of H_2O_2 and HNO_3 for plants and $Li_2B_4O_7$ - $LiBO_2$ for soils and were analysed. The analyses were carried out to determine the concentration of these metals in soil, their accumulation and translocation in plant parts. The data acquired were evaluated using bioconcentration (BCF), translocation factor (TF), bioaccumulation coefficient (BAC), metal uptake efficiency (ME%) and hierarchical cluster analysis to determine hyperaccumulators, phytoextractors, phytostabilizers, metal source plants and metals that could be toxic to humans through intake of roots, grains/seeds, fruits and leaves as vegetables. ANOVA analysis revealed that the data were significant at $p < 0.05$. Correlation and cluster analyses were employed to understand the relationships between variables determined. From this study, CA, COA and LA were hyperaccumulators of Co at various points. Arsenic has only phytostabilizers. COA and LA were phytostabilizers of Cd while Sida acuta was the only phytoextractor. Chromium, Co and Cd have prospect of being phytomined from some of the plants. Vegetables/edibles values in shoots and leaves were above permissible levels for Cr, Co and Cd. The metal uptake efficacy (%) were in this order Co (28.99 to 89.08) > Cd (21.74 to 50.96) >Cr (22.90 to 49.06) > and As (9.65 to 39.19).

Introduction

Trace (some toxic) metals occur naturally in all soils in low concentrations. However, the level of these metals have greatly increased due to human activities such as wastes generation (domestic and municipal), industries such as textile, battery and auto workshops, mining activities, agriculture etc (Lago-Vila et al., 2015; Mganga, 2014).Under elevated conditions in the environment, these toxic metals in soils pose enormous threat not only to plants but also to humans via the food chain. This is because the metals are persistent in the environment, non-biodegradable and are easily translocated from plants to animals and humans. While metals such as Co, Ni, Zn, Cu are essential nutrients to plants, others such as Hg, Cd, Cr have no known biological functions (Opaluwa et al, 2012; Mganga, 2014).

Discharged chemical and effluent wastes affect the environment by mobilization of hazardous constituents which contaminate soil, water and vegetations (Ahmed et al, 2010). Metal contaminations arising from industrial wastes, discharge and leachates into the soil are threats to resources, human health and other living organisms. Soil pollution is of and a global concern with increasing severity due to urban growth, industrialization and changing lifestyles. These soil pollution problems are visibly with us today, especially in developing countries like Nigeria. Land degradation is taking place today as a result of soil erosion, deforestation and soil pollution (Lago-vila etal, 2015).

The use of plants is an economically and ecologically friendly alternative to conventional techniques for decontamination/stabilization of toxic metal polluted sites (Suman et al., 2018). Plants have inherent ability to absorb toxic substances, including trace elements along with nutrient materials from the soil. The non-essential, toxic metals are known to cause plant toxicity and occur in various soluble and particulate materials which also affect their bioavailability and mobility. These toxic metals have tendency to accumulate in soft tissues of living organisms (Rangnekar et al, 2013). Remediation of metal polluted soil is still a global challenge to both administrators and researchers due to the non-degradability of these metals in the environment. Phytoremediation, which is a harmless procedure that respect the environment and a biological technology using plants to remove contaminants from soil, has been on the search light due to its cost effectiveness and environmental harmonies (Ahmed et al, 2010; Lago-Vila et al, 2015). Metal pollution causes major environmental and human health problems and therefore need our immediate attention for effective and affordable techniques of remediation from polluted soil. Phytoremediation uses plants to clean-up trace elements contamination and it is an environmentally friendly method. The uptake of these trace elements and accumulation varies from plant to plant and from species to species within a genus (Ahmed et al, 2010). This method uses plants to remove toxic elements from the contaminated soil through metal accumulation in harvestable shoot part or to immobilize metals in soil by root uptake, adsorption to root surfaces or precipitation in the rhizosphere. Reclaiming contaminated soil through plants and indeed native plants is most desirable and advantageous because of their survival rate, growth and reproduction under already polluted soil over imported or engineered, foreign plants (Nazir etal; 2011).

Hyperaccumulator plants have the capacity to absorb and translocate metals from their roots to the shoots and equally have high tolerance for these metals without phytotoxicity symptoms (Suman et al.,2018). Hyperaccumulators require enormous energy for the mechanisms required to adapt to high metal concentrations in their tissues (Lago-Vila etal, 2015). Plants with potential for phytoextraction are capable of growing in soils with high degree of metals because of their large radicular system, high level of biomass production and are able to accumulate high concentration of metals in shoot (Lago-Vila etal, 2015). Phytoextraction means metal content reduction in soil, translocation to above-ground tissues and this technique is used to reduce damage caused to the soil. In cases where phytoextraction is not feasible, phytostabilization can be adopted. This means immobilizing the metals in the soil, stabilizing/detoxifying contaminated soils and thereby reducing the flow or distribution of contaminants into the environment (Suman et al.,2018). In phytostabilization method, the plants do not accumulate metals in their shoots. This also minimizes the risk in terms of food safety for vegetables and roots, seed/grains, fruits that are edible. Hyperaccumulator plants can take up concentrations of > 10,000.00mg/kg of Zn or Mn; 1,000.00mg/kg and above of As, Co, Cr, Cu, Ni, Pb, Sb, Se and Ti or 100mg/kg of Cd (Verbruggen et al, 2009).According to Lorestani et al., (2011), hyperaccumulator plants must also have TF or EF>1 in addition to above criteria.

This research is hinged on the hypotheses that (i) the native plants are more adapted to the soil and pollutants (ii) these plants can accumulate and translocate metals from the polluted soil to the aboveground tissues (iii) some of these plants have the potential for removal and stabilization of these

metal pollutants (iv) because of effective and efficient translocation to shoots and leaves, some plants could serve as reservoir for extraction of these metals (v) some of these plants if consumed by humans and animals could pose health hazards.

The objectives of this study are therefore, to (i) identify and determine metal concentrations in native plants and edibles/vegetables in study soil (ii) compare metal concentrations in soils and plants tissues (iii) determine the metal accumulation and translocation factors from soil to the aerial biomass of the plants (iv) evaluate their potentials for hyperaccumulation, phytoextraction and phytostabilization, (v) highlight plants with both phytomining potential and harmful effects if consumed in excess by humans.

Phytoremediation and phytomining are therefore needed to address environmental and socio-economic concern in dump sites. There is therefore, the need to identify plants which remove metals from soil in large amount, after which valuable metals can be recovered economically and taking note of those with potential to cause harm when consumed. Over time, land is made available for other socio-economic uses once the polluted level has been reduced to minimal and acceptable levels.

Materials And Methods

The area under study is a metropolitan City. The sources of wastes in the area are enormous and include municipal and domestic wastes, hospital wastes, auto body and battery repair workshop wastes, textile and dying activities, agriculture and agricultural produce etc. Waste sites were surveyed and located for sample collection. The study area is between longitude 7°10′0″E and 7°12′0″E and latitude 7 °28′0″N and 7 °31′0″N.

2.1 Plant sample collection

Ten plant species were collected and the researchers ensured that different plant samples of each species have same physiology, identical size and appearance (Ng et al; 2018).Plant samples collected were representative of available plant species. The plant species collected from the contaminated sites include grasses, edibles and vegetables. Some plants were sampled twice from two different sites while others were collected three and four times from different sites, respectively. Plant samples were collected carefully using a clean plastic hand trowel to dig the soil and were gently removed to ensure no part was lost (Rangnekar et al, 2013). The plant samples were washed thoroughly first with tap water and later with distilled water to remove adherent soil and contaminants. The plants were sectioned into roots, shoots and leaves and stored temporarily in self-sealing and well- labeled plastic bags. In the laboratory, all plant materials were oven-dried for 72hours at 70°C to obtain a constant dry matter yield, crushed and homogenized in a mortar using pestle and were stored in sealed polyethylene bags ready for analysis (Yoon et al, 2006; Ahmed et al, 2010).

2.2 Soil sample collection

Soil samples were collected from the rhizosphere (0cm-20cm depths) at each previously sampled plant points. The samples were screened for pebbles, dirt, sticks etc. Equal subsamples of the soil were mixed or homogenized thoroughly and a composite sample taken (Baker and Brooks, 1989). The samples were oven-dried at 105°C for complete moisture removal and passed through 2mm sieve using a magnetic sieve shaker to collect the fine fraction for further analysis (Yoon et al, 2006).

2.3 Metal extraction from plants and soils

2.0grams of the powdered plant tissues were digested with H_2O_2 and HNO_3 in a microwave oven (Bell et al, 2000; Lago-Vila et al, 2014). This was continued till a minimal clear layer of acid was obtained. After cooling, the content was filtered through Whatman filter paper number 41. Final volume of 25ml was made in a clean volumetric flask using 0.25% of HNO_3 (Allen, 1989; Marin etal; 1993).

Total metal content in soil was determined by fusion method with $Li_2B_4O_7$. $LiBO_2$. 1.0g of sample with 3.5g of $Li_2B_4O_7LiBO_2$ flux (50/50 w/w) and 1.0g of LiI in a platinum crucible (Hill, 2008). The mixture, a heated propane-perl induced machine was fused for 10-15minutes. The content of the crucible was poured into Teflon precipitate flask containing 100L of HNO_3 and magnetically shaken to dissolve the fused mixture. The mixture was transferred to a 500ml flask and made up to volume with 5% HCL. The filtrate of both plants and soil were analyzed for metal content using EDX3600B X-ray Fluorescence Spectrometer (Skyray Instruments Inc., USA) at Nanotechnology and Advanced Materials, National Agency for Science and Engineering Infrastructure (World Bank Assisted Project) Centre, Akure, Nigeria.

The analytical range of elements by EDX3600B metal analyser is between (Mg, Z = 12) and Uranium (U, Z = 92) with high resolution and accuracy of 0.05% and detection limit of 0.01ppm.The pure silver sample was used to calibrate the instrument before use (Aksoy et al. 2014).

Each sample of plants and soil were digested in replicates for consistency of results. Blanks were run in replicates to check the precision of the method with each set of sample (Rangnekar etal, 2013). The standard reference materials for Cr, Cd, As and Co (Merck-E grade, Germany) were used for calibration and quality assurance. Analytical data, the quality of metals were ensured through replicate analysis of standard reference samples. The obtained results were within ±2.05% to 2.85% of certified values. The mean recovery of 98% to 99.95% was achieved for different metals.

2.4 Data evaluation methods

(i) Bioconcentration faction (BCF): This is the metal uptake capacity from soil to plant tissues. The BCF was calculated as metal concentration in the plant root, shoot and leaves to metal concentration in soil (Ghosh et al; 2005; Mganga et al; 2014; Lago-Vila et al; 2015).

(ii) Translocation factor (TF): Translocation factor indicates preferential partitioning of metals to shoot and leaves. Plants with higher translocation factor have greater accumulation ability. The TF was calculated as the ratio of metal concentrations in plant's shoot and leaves to concentration of metal in corresponding root (Gupta et al, 2008; Singh et al, 2010; Brooks and Baker, 1989; Yanhong et al, 2013). Translocation of metals from roots to other plant parts is useful in monitoring metal contamination and selection of metal accumulator or tolerance species (Singh et al, 2010). This index also shows which plants can be phytomined and that which can harm humans when the edible parts are consumed.

(iii) Bioaccumulation Coefficient (BAC): is dependent on the soluble fraction of metals in soil (Ahmed et al, 2010). The BAC is calculated as the ratio of metal concentration above ground parts of plants (shoot & leaf) to metal concentration in soil on dry weight (Iya et al, 2018; Anwar et al, 2010).

(iv)Enrichment factor (EF1): is calculated as the ratio of plants leaf concentration to soil concentration (Branquinho et al., 2006)

(v)Metal uptake efficacy (%): is the ratio of metal accumulated in shoot/ total metal concentration removed from the soil media ×100 (Ng et al., 2018)

(vi) ANOVA and Hierarchical cluster analyses: The ANOVA, correlation and hierarchical analyses were performed using SPPS version 20. All the data generated by ANOVA in this study were significant at $p<0.05$. The correlation matrix based on Pearson's correlation coefficient was used to display relationships between variables. Only variables between +1 and -1 were used (Yang et al., 2009).

Hierarchical cluster analysis was used to group similar variables. Evaluations of similarities were based on the average linkage between groups. Cluster analysis was performed on the normalized data sets by means of the Ward's method, using squared Euclidean distances as a measure of similarity (Laluraj et al., 2005). Objects were grouped such that similar objects fall into the same class. Hierarchical clustering joins the most similar observations and successively the next most similar observations (Lokhande et al., 2008). The levels of similarity at which observations were merged were used to construct the dendogram. A short distance indicates that two objects were similar, whereas a long distance shows dissimilarity. Hierarchical cluster using dendograms identifies relatively homogeneous groups of variables with similar properties and combines clusters until only one is left (Praveena et al., 2007).

Results And Discussions

Chromium (Cr).

Cr concentrations in soils from the waste dumps in the study area range from19.00 in site 4 to 118.00mg/kg in site 7 with standard error of 5.32 and standard deviation of 27.66 (Tables 1a and b). According to Rudnick and Gao, 2003, the upper continental crust limit of Cr in soil is 92.00mg/kg; 2.00mg/kg (Vinogradov, 1954) and 42.00mg/kg by Kabata- Pendias, 2001 (Table 1b). The average concentration of Cr in soils from study area was higher than the uncontaminated references. The elevated value of Cr observed may be due to pollution from the dumps. In a similar study, 1366 ± 49mg/kg to 2689 ± 82mg/kg of Cr were recorded in soil (Lago-Vila et al., 2015). The accumulation content of Cr in roots varied from 2.00mg/kg in Amaranthus hybridus in site 3 to 120.00mg/kg in Laportea aestuans in site 7. The standard deviation and error were 26.70 and 5.14 respectively (Table 1b and Figure 2a). Compared to the soil concentration of Cr in study area, the level of Cr in roots were higher in three locations. On the average, Cr concentrations in soil were all higher than in roots (Table1a and Figure 2a). In another study, 19.63 ± 1.79mg/kg and 29.49 ± 3.40mg/kg were accumulated in roots of Festuca rubra L. and Juncus sp.L respectively (Lago-Vila et al, 2015).

Table 1a: Concentration of Cr (mg/kg) in soils and plant tissues.

Scientific name	Site no.	Soil	Root	Shoot	Leaf	BCF	TF	BAC	TF_l	EF_l	ME% Shoot
Amaranthus hybridus *AH	1	42.33	5.00	2.00	3.00	0.12	0.40	0.04	0.60	0.07	27.54
	3	30.33	2.00	3.00	1.00	0.07	1.50	0.10	0.50	0.03	
	4	19.00	9.00	4.00	2.00	0.47	0.44	0.21	0.22	0.11	
Average values	5	56.00	21.0	10.00	7.00	0.38	0.48	0.18	0.33	0.13	
		36.92	9.25	4.75	3.25	0.26	0.71	0.13	0.41	0.09	
Amaranthus viridis *AV	3	30.33	12.00	1.00	0.00	0.40	0.08	0.03	0.00	0.00	33.61
	4	19.00	11.00	4.00	3.00	0.58	0.36	0.21	0.27	0.16	
	6	58.33	34.00	20.00	12.00	0.58	0.59	0.34	0.35	0.21	
Average values	7	118.0	95.00	100.00	56.00	0.81	1.05	0.85	0.59	0.48	
		56.42	38.00	31.25	23.67	0.59	0.52	0.36	0.40	0.28	
Abelmoschus esculentus *AE	4	19.00	6.00	15.00	8.00	0.32	2.50	0-79	1.33	0.42	43.56
Average values	7	118.0	65.00	100.00	70.00	0.55	1.54	0.85	1.08	0.59	
		68.50	35.50	57.50	39.00	0.44	2.02	0.82	1.21	0.51	
Cucurbita maxima *CM	2	52.33	15.00	2.00	1.00	0.29	0.13	0.04	0.07	0.02	32.39
	5	56.00	40.00	32.00	15.00	0.71	0.80	0.57	0.38	0.28	
Average values											
		54.17	27.50	17.00	8.00	0.50	0.47	0.31	0.23	0.15	
Colocasia asculenta *CA	5	56.00	17.00	30.00	18.00	0.30	1.76	0.54	1.06	0.32	49.06
	6	58.33	36.00	48.00	10.00	0.62	1.33	0.82	0.28	0.17	
Average values											
		57.17	26.50	39.00	14.00	0.46	1.55	0.68	0.67	0.25	
Corchorus aestuans *COA	6	58.33	30.00	10.00	2.00	0.51	0.33	0.17	0.07	0.03	34.36
	2	52.33	42.00	19.00	7.00	0.80	0.45	0.36	0.17	0.13	
Average values	1	42.33	50.00	49.00	18.00	1.18	0.90	1.16	0.36	0.43	
		51.00	40.67	26.00	9.00	0.83	0.59	0.56	0.20	0.20	
Laportea aestuans *LA	1	42.33	28.00	11.00	4.00	0.66	0.39	0.26	0.14	0.09	39.71
	2	52.33	38.00	49.00	30.00	0.73	1.29	0.94	0.79	0.57	
Average values	7	118.0	120.00	102.00	26.00	1.02	0.85	0.86	0.22	0.22	
		70.89	62.00	54.00	20.00	0.80	0.84	0.69	0.38	0.29	
Physalis angulata *PA	2	52.33	22.00	38.00	16.00	0.42	1.73	0.73	0.73	0.31	43.48
	6	58.33	14.00	12.00	13.00	0.24	0.86	0.21	0.93	0.22	
Average values											
		55.33	18.00	25.00	14.50	0.33	1.30	0.47	0.83	0.27	
Sida acuta *SA	1	42.33	40.00	80.00	13.00	0.95	2.00	1.89	0.33	0.31	44.19
	4	19.00	15.00	10.00	11.00	0.79	0.67	0.53	0.73	0.58	
	3	30.33	32.00	9.00	14.00	1.06	1.06	0.30	0.44	0.46	
Average values		30.55	29.00	33.00	12.67	0.93	1.24	0.91	0.50	0.45	
Zea mays *ZM	3	30.33	26.00	8.00	6.00	0.86	0.31	0.26	0.23	0.20	22.90
	5	56.00	39.00	22.00	30.00	0.70	0.56	0.39	0.77	0.54	
Average values		43.17	32.50	15.00	18.00	0.78	0.44	0.33	0.50	0.37	

*Short code for plants name

Table 1b: Summary statistics of Cr in soil and plant tissues

Variable	Minimum	Maximum	Mean		Std. Deviation
	Statistic	Statistic	Statistic	Std. Error	Statistic
Soil	19.00	118.00	51.38	5.32	27.66
Root	2.00	120.00	32.00	5.14	26.70
Shoot	1.00	102.00	29.26	6.13	31.86
Leaf	.00	70.00	14.67	3.15	16.38
BCF	.07	1.18	.69	.06	.29
TF	.08	2.50	.91	.12	.62
BAC	.00	1.89	.48	.08	.43
TFl	.00	1.33	.48	.06	.35
EFl	.00	.59	.26	.036	.19

Table 1c: Uncontaminated soil and vegetable standard values

Element mg/kg(soil)	Rudnick and Gao, 2003	Vinogradov, 1954	Vinogradov, 1954	Kabata-Pendias, 2001	Bradford et al., 1996	Papadopoulos et al., 2015	Element mg/kg (vegetable)	WHO, 1996	WHO/FAO, 1993	Podlesakova et al., 2002
Cr	92.00	2.00	80.00	42.00	-	64.00	Cr	1.30	-	-
Co	17.00	8.00	10.00	7.00	14.90	40.00	Co	0.02	-	6.00
As	05.00	05.00	05.00	05.00	0.80	-	As	0.20	-	2.00
Cd	0.10	-	-	-	0.36	1.400	Cd	0.02	1.00	1.10

Table 1d: Sampled plants and their edible parts

Scientific name	Edible part
Amaranthus hybridus	Grains as food crop and leaves
Amaranthus viridis	Seed and leaves
Abelmoschus esculentus	Green seed pod
Cucurbita maxima	Seed, fruit and leaves
Colocasia asculenta	Corms,roots and leaves
Corchorus aestuans	Leaves
Laportea aestuans	Mucilaginous leaves
Physalis angulata	Fruit
Sida acuta	Not edible but medicinal
Zea mays	Grains/seed and as vegetables

According to Iya et al (2018), the highest accumulation of Cr in root of A. wilkesiana was 101.23 ± 2.92mg/kg (Table1a and Figure 2a). The shoot content of Cr in plants varied from 1.0mg/kg in Amaranthus viridis, (site 3) to 102.00mg/kg in Laportea aestuans in site 7 (Table 1). Iya et al (2018), observed the highest concentration of 76.93 ± 1.27mg/kg of Cr in A. wilkesiana shoot. Singh et al (2010), recorded Cr values in the range of 2.54 to 0.08mg/g in the shoots of plants. These were both lower than obtained range from this area.This is an indication of higher accumulation and translocation of Cr to the shoots in study area. Hyperaccumlators of Cr must concentrate up to 0.10% of Cr with TF or EF>1 (Verbruggen et al, 2009). Mongkhonsin et al, (2011); Reeves and Baker, (2000); Lorestani et al., 2011 and Tappero et al, 2007 considered a plant hyperaccumulator of Cr based on, (i) that Cr concentration in

shoot be > 50mg/kg (ii) that the concentration of Cr in aerial biomass is 10-500 times greater than in the non-metallophyte (0.2-5mg/kg of Cr), (iii) TF or EF>1 and (iv) that Cr concentration in the shoot is greater than in the roots. Based on (i, iii and iv) definitions, Amaranthus viridis at site 7 (100mg/kg), Abelmoschus esculentus site 7 (100mg/kg); Laportea aestuans (102.00mg/kg of Cr) and Sida acuta (80.00mg/kg of Cr) at site 1 were all hyperaccumulators of Cr. The intake of Cr by the leaves was generally lower compared with the stem and root (Table 1 and Figure 2a) According to Cirua et al., 2005, Cr is predominantly immobilized in the roots with much less Cr in leaves. The Cr concentration ranged from 70.00mg/kg in Abelmoschus esculentus, (site 7) to 1.00mg/kg (sites 3 and 1) in Amaranthus hybridus and Cucurbita maxima in site 2 (Table 1b). Mellem et al (2012) recorded Cr accumulation of 17.0 ± 1 to 118.0 ± 1 in A. dubius leaves from a similar study. The WHO, 1996 permissible limit of Cr in leaves or vegetables is 1.30mg/kg (Table 1c). This suggests that edibles/vegetables among sampled plants have excess of Cr and may not safe for human intake as the leaf concentrations among plants were <1.30mg/kg in only three locations. This is because Cr in the body can result in acute kidney failure, long term risk for lung cancer, contact dermatitis etc (Mediolla et al., 2008).

The BCF, TF and BAC for shoots and leaves

The BCF were all less than 1 for Cr except at sites 1, 7 and 3 for Corchorus aestuans, Laportea aestuans and Sida acuta where BCF > 1 was observed (Table 1 and Figure 2b). This shows that the roots were not tolerant to Cr accumulation from the soil. This is in agreement with the finding of Ciura et al., 2005, where they states that translocation of Cr from roots to shoots is extremely limited. The BCF ranged from 0.07 to 1.18 in study area (Figure 2b). In R. acetosa, BCF range of 0.15 to 0.24 was observed while in U. dioica, BCF varied from 0.02 to 0.04 (Balabanova et al; 2015). The only phytoextractor of Cr in the area is Sida acuta in site 3 and a good plant for phytomining. Plants with BCF > 1, TF or EF< 1 are suitable for phytostabilization of Cr. Therefore, COE (site 1) and LA are phytostabilizers of Cr. The TF values for Cr were slightly higher in most sampled points than the BCF. Contrary to Cr soil-root accumulation, the plants under study tolerated and accumulated Cr from root to the shoot. This is contrary to Ciura et al., 2005 that accumulation in roots is 100-fold higher than shoots. This tolerance and ability to accumulate Cr in shoot shows their potential for phytomining (Singh et al, 2010). The TF of Cr from the study ranged from 0.08 to 2.50. This indicates relative ability to accumulate Cr in above ground tissues. Mellem et al, (2012) observed TF range of 0.5 to 1.1 for Cr. Also Singh et al, (2010), recorded TF value of 0.73 for Cr in a similar study. The BAC, which is the root to leaf translocation and soil to leaf accumulation were mostly < 1 in most points. These suggest relatively lower ability of the plants to translocation and accumulation Cr in leaves of plant species under investigation. The efficacy of Cr uptake ranged from 22.90% in ZM to 49.06% in CA. This value is below the average metal uptake for Cr (Table 1a)

Table 1d: Correlations among variables

	Soil	Root	Shoot	Leaf	BCF	TF	BAC	TFone	EFone
Soil	1	.594	.717*	.619	-.170	.311	.238	.344	.135
Root	.594	1	.674*	.436	.656*	-.102	.439	-.171	.315
Shoot	**.717***	**.674***	1	.761*	.225	.649*	.810**	.513	.635*
Leaf	.619	.436	**.761***	1	.026	.550	.481	.718*	.777**
BCF	-.170	**.656***	.225	.026	1	-.284	.458	-.411	.389
TF	.311	-.102	**.649***	.550	-.284	1	.698*	.881**	.582
BAC	.238	.439	**.810****	.481	.458	**.698***	1	.437	.737*
TFone	.344	-.171	.513	.718*	-.411	**.881****	.437	1	.647*
EFone	.135	.315	**.635***	**.777****	.389	.582	**.737***	**.647***	1

*. Correlation is significant at the 0.05 level. **. Correlation is significant at the 0.01 level.

At 0.01 level of significant, shoot-BAC (r=.810), leaf-EFone (r=.777) and TF-TFone (r=.881) showed very high relationship. This is a reflection of the fact that between the two variables each above, there seems to be no difference between the concentration of metals accumulated and translocated from one variable to the other (Poniedzialek et al., 2010). Given the level of significant at 0.05, soil-shoot (r=-717), root-shoot (r=.674),root-BCF (r=.656), shoot-leaf (r=.761), shoot-TF (r=.649), shoot-EFone (r=.635), leaf-TFone (r=.718), TF-BAC (r=.698), BAC-EFone (r=.737) and TFone-EFone (r=.647). The relationship at 0.05 level is strong but at 0.01, it is stronger. It means that between the pair of variables, there exist a good connectivity to the extent that of all accumulations, more than half were translocated to avoe plants parts (Table 1d).The negative correlation (soil-shoot) indicate accumulation but reduced biomass due to soil contamination and low shoot tolerance to Cr.

The dendogram consist of two clusters. Cluster one is a union of TF-TFone, shoot-BAC, leaf-EFone and soil alone. Soil in this cluster, shows the greatest dissimilarity to all the variables. This by implication means that the concentrations of metals in soils were not proportional to that in plants part. In the same cluster, TF-TFone, shoot-BAC and leaf-EFone showed decreasing similarities in that order. The pair of variables with the greatest similarity shows that the metal content in the pair were not different in terms of their concentrations and what was translocated. Cluster two is an association of only root-BCF. The highest degree of dissimilarity is shown in this cluster except the soil. This dissimilarity suggests that the metal content of one variable has no relationship with the content of another variable in the same pair (Figure 2c).

Cobalt (Co).

Co concentrations in soil samples range from 1536.67mg/kg in site 1 to 3240.47mg/kg in site 6 (Table 2a and b). Co in uncontaminated soil is 7.00mg/kg (Kabata- Pendias, 2001); 14.90mg/kg (Bradford et al., 1996) and 40.00mg/kg (Papadopoulos et al, 2015). The concentrations cited are way below the study area concentration. This could suggest soil pollution from the wastes dumps in the area (Table 2a). The root accumulated the highest concentration of Co (612.00mg/kg) in Colocasia asculenta and the least (0.00mg/kg) in AH, AV, AE, CM, LA and PA at various points (Table 2a and b). The shoot on the other hand recorded the highest accumulation of Co (1215.0mg/kg) in Laportea aestuans and the least value of 0.00mg/kg in Amaranthus viridis at location 7. Over all, the shoot accumulated more Co than any other plant tissue (Table 2b).This shows that Co is readily absorbed by roots and transported to the shoot. Sometimes also, Co can be accumulated higher in shoots even though its concentration in soil is low (Ciura et al., 2005). The highest Co concentration in leaf (152.00mg/kg) was recorded in Zea mays while Amaranthus hybridus recorded 0.00mg/kg of Co. This is possible because Zea mays grow rapidly and have high biomass production (Suman et al., 2018) The permissible value of Co in vegetables is 0.02mg/kg (WHO, 1996) and 6.00mg/kg (Podlesakova et al., 2002). Both limits are lower than the average Co in vegetables from the area. All the values recorded in the leaves were higher than the permissible level except at four locations (Table 2a). Food safety with respect to Co contents in vegetable intake require attention even though Co is an essential nutrient for both plants and humans (Table 2c). Co has been implicated for causing cardiomyopathy, polycythemia and cancer (Huu et al., 2010). Hyperaccumulators of metals are plants that accumulate > 1000mg/kg of Co, Cu, Cr, Ni or Pb, or > 10,000mg/kg of Fe, Mn and Zn in their shoots and TF or EF>1 (Verbruggen et al, 2009; Mongkhonsin et al, 2011; Lorestani et al.,2011; Reeves and Baker, 2000; Baker

Table 2a: Concentration of Co (mg/kg) in soils and plant tissues.

Scientific name	Site no.	Soil	Root	Shoot	Leaf	BCF	TF	BAC	TF_l	EF_l	ME (%) Shoot
Amaranthus hybridus *AH	1	1536.67	0.00	6.00	0.00	0.00	0.00	0.00	0.00	0.00	30.56
	3	1685.00	0.00	1.00	10.00	0.00	0.00	0.00	0.00	0.01	
	4	2654.00	12.00	1.00	5.00	0.00	0.08	0.00	0.42	0.00	
Average values	5	2415.33	21.00	14.00	2.00	0.01	0.67	0.01	0.10	0.00	
		2072.75	8.25	5.50	4.25	0.00	0.19	0.00	0.13	0.00	
Amaranthus viridis *AV	3	1685.00	0.00	18.00	11.00	0.00	0.00	0.01	0.00	0.01	28.99
	4	2654.00	0.00	12.00	7.00	0.00	0.00	0.00	0.00	0.00	
	6	3240.67	0.00	19.00	10.00	0.00	0.00	0.01	0.00	0.00	
Average values	7	2687.00	0.00	0.00	9.00	0.00	0.00	0.00	0.00	0.00	
		2566.67	0.00	12.25	30.25	0.00	0.00	0.01	0.00	0.00	
Abelmoschus esculentus *AE	4	2654.00	15.00	32.00	16.00	0.01	2.13	0.01	1.07	0.01	51.52
Average values	7	2687.00	0.00	2.00	1.00	0.00	0.00	0.00	0.00	0.00	
		2670.50	7.50	17.00	8.50	0.01	1.07	0.01	0.54	0.01	
Cucurbita maxima *CM	2	2203.00	0.00	4.00	8.00	0.00	0.00	0.00	0.00	0.00	44.44
	5	2415.33	2.00	36.00	40.00	0.00	18.00	0.01	20.00	0.02	
Average values		2309.17	1.00	20.00	24.00	0.00	9.00	0.01	10.00	0.01	
Colocasia asculenta *CA	5	2415.33	403.00	1200.00	45.00	0.17	2.98	0.50	0.11	0.02	66.95
Average values	6	3240.67	612.00	1020.00	36.00	0.19	1.67	0.31	0.06	0.01	
		2828.00	507.50	1110.00	40.50	0.18	2.33	0.41	0.09	0.02	
Corchorus aestuans *COA	6	3240.67	52.00	70.00	32.00	0.02	1.35	0.02	0.62	0.01	89.08
	2	2203.00	81.00	1000.00	12.00	0.04	12.35	0.45	0.15	0.01	
Average values	1	1536.67	43.00	1052.00	40.00	0.03	24.47	0.68	0.93	0.03	
		2326.78	58.67	707.33	28.00	0.03	12.72	0.39	0.57	0.02	
Laportea aestuans *LA	1	1536.67	0.00	1215.00	22.00	0.00	0.00	0.79	0.00	0.01	83.59
	2	2203.00	300.00	68.00	20.00	0.14	0.23	0.03	0.07	0.01	
Average values	7	2687.00	83.00	1075.00	38.00	0.03	12.95	0.40	0.46	0.01	
		2142.22	127.67	786.0	26.67	0.06	4.39	0.41	0.18	0.01	
Physalis angulata *PA	2	2203.00	273.00	322.00	65.00	0.11	1.36	0.15	0.27	0.03	48.47
Average values	6	3240.67	0.00	10.00	15.00	0.00	0.00	0.00	0.00	0.00	
		2721.84	136.50	166.00	40.00	0.06	0.68	0.08	0.14	0.02	
Sida acuta *SA	1	1536.67	27.00	51.00	31.00	0.02	1.89	0.03	1.15	0.02	38.71
	4	2654.00	120.00	60.00	25.00	0.05	0.50	0.02	0.21	0.01	
	3	1685.00	300.00	232.00	40.00	0.18	0.77	0.14	0.13	0.02	
Average values		1958.56	149.0	114.33	32.00	0.083	1.05	0.06	0.50	0.02	
Zea mays *ZM	3	1685.00	96.00	100.00	37.00	0.06	1.04	0.10	0.39	0.02	36.06
	5	2415.33	318.00	240.00	152.00	0.13	0.75	0.10	0.48	0.06	
Average values		2050.17	207.00	170.00	94.50	0.10	0.90	0.10	0.44	0.04	

*Short code for plants name

Table 2b: Summary statistics of Co in soil and plant tissues

Variable	Minimum	Maximum	Mean		Std. Deviation
	Statistic	Statistic	Statistic	Std. Error	Statistic
Soil	1536.67	3240.67	2333.32	109.35	568.21
Root	.00	612.00	102.15	30.52	158.60
Shoot	.00	1215.00	291.11	85.86	446.14
Leaf	.00	152.00	27.00	5.75	29.90
BCF	.00	.19	.04	.01	.06
TF	.00	24.47	3.08	1.20	6.24
BAC	.00	.79	.14	.04	.23
TFl	.00	20.00	.99	.73	3.82
EFl	.00	.06	.01	.00	.01

and Brooks, 1989). From the study data, Colocasia asculenta; Corchorus aestuans (sites 2 &1); Laportea aestuans (sites 1and 7) were all hyperaccumulators of Co and are therefore suitable for phytoremediation of Co contaminated soil in the area (Table 2a). The minimum, maximum values of Co in soil and tissues are presented in table 2b with their respective standard deviation and error. In some sites, the plant leaves revealed higher accumulation of Co than in the roots. This may suggest a situation whereby shoot to leave translocation of Co is better than soil to roots accumulation. CA, COA, and AE,CM,LA,PA,SA and ZM (one site each) that accumulated and translocated more Co to above parts are plants that are not only suitable candidates for phytoremediation but also have potential for phytomining of Co in their above ground tissues. Where this metal is in excess in vegetables/edibles and are taken by man, it can also become toxic. In a similar study, the leaves accumulated more of Co, followed by stem and then the roots. Based on this previous study, A. wilkesiana recorded 2.92 to 87.87mg/kg in leaves; 81.63mg/kg in shoot and 50.19mg/kg in roots (Iya et al, 2018). Also, 5.17 to 8.17mg/kg and 0.92 to 1.10mg/kg were observed in shoots of Festuca rubra L. and Juncus sp.L respectively. In the roots of Festuca, 19.63 to 77.04mg/kg and in Juncus, 25.53 to 29.49mg/kg were observed (Lago-Vila et al, 2015).This result is in contrast to the observation Iya et al., (2018).

The BCF, TF, BAC for both shoots and leaves

The BCF for Co were all < 1 in the study area. This suggests limited accumulation of Co by the roots from the soil. This is an indication that the roots were excluders of Co (Table 2a and b). Interestingly too, the translocation factor of Co was very high in some locations. Translocation factor ranged from 0.23 in Laportea aestuans to as high as 24.47 in Corchorus aestuans (Tables 2a, 2b and Figure 3b). The high TF could suggest that these two plants and few others at one location each may be suitable source for mining of Co. The BAC for plants were all < 1. The root to leaf translocation was > 1 (in three sampled plants at three locations). Soils to leaf accumulations were all < 1(Table 2a and Figure 3b). These observations show high translocation but low accumulation in these respective tissues.

The TFs in study area were contrary to TFs of < 1 recorded for Festuca and Juncus. The current result is also in contrast to BCF recorded in roots of Festuca and Juncus which were 1. The BAC for shoots agrees with the < 1 values obtained for Juncus sp. L (Lago-Vila et al, 2015). From this study, no plant is suitable as phytoextractor and phytostabilizer of Co but high values of TFs were recorded in some plant's shoot. Metal uptake for Co is highest among the metals under study. ME for Co ranged from 28.99 to 89.08%.

Table 2c: Correlations among variables

Variable	Soil	Root	Shoot	Leaf	BCF	TF	BAC	TFone	EFone
Soil	1	.292	.235	-.152	.163	-.089	-.240	-.086	-.303
Root	.292	1	.729*	.464	.984**	-.158	.041	-.283	.440
Shoot	.235	**.729***	1	.123	.694*	.355	.446	-.264	.167
Leaf	-.152	.464	.123	1	.537	-.129	-.081	-.119	.926**
BCF	.163	**.984****	**.694***	.537	1	-.169	.061	-.316	.539
TF	-.089	-.158	.355	-.129	-.169	1	.112	.496	.051
BAC	-.240	.041	.446	-.081	.061	.112	1	-.132	-.099
TFone	-.086	-.283	-.264	-.119	-.316	.496	-.132	1	-.082
EFone	-.303	.440	.167	**.926****	.539	.051	-.099	-.082	1

*. Correlation is significant at the 0.05 level. **. Correlation is significant at the 0.01 level .

The correlation between root-shoot(r=.729) and shoot-BCF (r=.694) were the only relationship revealed at significant level of 0.05. The two pairs of correlations were strong. This may suggest that the roots accumulated and translocated Co proportionally to the shoot. At 0.01 level, the root-BCF (r=.984), and leaf-EFone (r=.926) revealed very strong correlation. It signifies that the concentrations of metals in each of these variables were not significantly different. Apart from these four pairs, all other variables showed less significant correlations (Table 2c).

Two clusters were extracted. The BCF, EFone, TFone, BAC, TF and root showed the same level of similarities and displayed the strongest similarities in cluster one. Also, in cluster one, shoot-leaf showed stronger similarity but not evidenced in the correlation. The more the degree of similarity, the more the likely hood of the variable to retain same concentration of metals in their tissues. Cluster two consists of only the soil. It suggests the soil has no relationship in terms of its concentration and what was accumulated in other parts of the plants (Figure 3c).

Arsenic (As).

The As in soil from study area ranged from 6.27 to 44.00mg/kg. According to Kabata-Pendias & Pendias (1992; 2001), the limit for As in unpolluted soil is 05 to 20mg/kg and 5.00mg/kg (Bowen, 1979). The background concentration of major and trace elements in California soils is 0.80mg/kg (Bradford et al, 1996). The range observed from the study area clearly showed elevated levels of As in sampled soils due to waste dumps (Tables 4a &b). The highest content of As in roots (60.00mg/kg) was recorded in Abelmoschus esculentus in site 4. The lowest concentration of As (1.00mg/kg) in roots was found in Colocasia asculenta (Table 4a,4b and Figure 4a). As accumulated in shoot varied from 1.00mg/kg to 52.00mg/kg. In leaves also, As recorded was between 1.00mg/kg to 9.00mg/kg (Figure 5a). The average of this range in leaves is higher than 0.20mg/kg limit of WHO,1996 and 2.00mg/kg by Podlesakova et al.,2002 (Table 4b). As is a known cause of systemic hypertension, anemia, liver necrosis, kidney failure and acute leukemia (Adriana, et al., 2008; Violante et al., 2010). Excess of it in edibles/vegetables may not be safe for consumption. On the whole, As accumulation was highest in roots, followed by shoot and lastly leaf (Table 4a and Figure 4a). In another study, the roots of Rumex

Table 4a: Concentration of As (mg/kg) in soils and plant tissues.

Scientific name	Site no.	Soil	Root	Shoot	Leaf	BCF	TF	BAC	TF_l	EF_l	ME (%) Shoot
Amaranthus hybridus *AH	1	2.67	4.00	10.00	2.00	1.50	2.50	3.75	0.50	0.75	35.14
	3	12.00	15.00	6.00	1.00	1.25	0.40	0.50	0.70	0.08	
	4	44.33	31.00	13.00	4.00	0.70	0.42	0.29	0.13	0.09	
Average values	5	10.67	12.00	10.00	3.00	1.12	0.83	0.94	0.25	0.28	
		17.42	15.50	9.75	2.50	1.14	1.04	1.37	0.24	0.30	
Amaranthus viridis *AV	3	12.00	7.00	4.00	1.00	0.58	0.57	0.33	0.14	0.08	9.65
	4	44.33	40.00	3.00	2.00	0.90	0.08	0.07	0.05	0.05	
	6	0.00	6.00	1.00	4.00	0.00	0.17	0.00	0.67	0.00	
Average values	7	40.00	29.00	0.00	2.00	0.73	0.00	0.00	0.07	0.05	
		32.11	20.50	2.67	4.50	0.74	0.27	0.20	0.23	0.06	
Abelmoschus esculentus *AE	4	44.33	60.00	15.00	6.00	1.35	0.25	0.34	0.10	0.14	18.49
Average values	7	40.00	45.00	12.00	8.00	1.13	0.27	0.30	0.18	0.20	
		42.17	52.50	13.50	7.00	1.24	0.26	0.32	0.14	0.17	
Cucurbita maxima *CM	2	19.00	4.00	6.00	9.00	0..01	1.50	0.32	2.25	0.47	36.67
Average values	5	10.67	2.00	5.00	4.00	0.19	2.50	0.47	2.00	0.37	
		14.84	3.00	5.50	6.50	0.10	2.00	0.40	1.42	0.42	
Colocasia asculenta *CA	5	10.67	1.00	0.00	1.00	0.09	0.00	0.00	1.00	0.09	37.50
Average values	6	0.00	1.00	3.00	2.00	0.00	3.00	0.00	2.00	0.00	
		10.67	1.00	1.50	1.50	0.05	1.50	0.00	1.50	0.05	
Corchorus aestuans *COA	6	0.00	5.00	1.00	3.00	0.00	0.20	0.00	0.60	0.00	31.78
	2	19.00	14.00	7.00	1.00	0.74	0.50	0.37	0.07	0.05	
Average values	1	2.67	6.00	1.00	0.00	2.25	0.17	0.37	0.00	0.00	
		10.84	8.33	4.50	1.33	1.50	0.29	0.25	0.34	0.02	
Laportea aestuans *LA	1	2.67	32.00	14.00	3.00	11.99	0.44	5.24	0.09	1.12	36.62
	2	19.00	43.00	16.00	1.00	2.26	0.37	0.84	0.02	0.05	
Average values	7	40.00	60.00	52.00	3.00	1.50	0.87	1.30	0.05	0.08	
		20.56	45.00	27.33	2.30	5.25	0.56	2.46	0.05	0.42	
Physalis angulate *PA	2	19.00	26.00	18.00	6.00	1.37	0.69	0.95	0.23	0.32	35.14
Average values	6	0.00	12.00	8.00	4.00	0.00	0.67	0.00	0-33	0.00	
		9.00	19.00	13.00	5.00	1.37	0.68	0.88	0.28	0.16	
Sida acuta *SA	1	2.67	4.00	3.00	1.00	1.50	0.75	1.12	0.25	0.37	39.19
	4	44.33	30.00	25.00	2.00	0.68	0.83	0.56	0.07	0.05	
	3	12.00	15.00	10.00	7.00	1.25	0.67	0.83	0.47	0.58	
Average values		19.67	16.33	12.67	3.33	1.14	0.75	0.84	0.26	0.33	
Zea mays *ZM	3	12.00	13.00	4.00	9.00	1.08	0.31	0.33	0.69	0.75	25.53
	5	10.67	10.00	8.00	3.00	0.94	0.80	0.75	0.30	0.28	
Average values		11.34	11.50	6.00	6.00	1.01	0.56	0.54	0.50	0.52	

*Short code for plants name

Table 4b: Summary statistics of As in soil and plant tissues

Variable	Minimum	Maximum	Mean		Std. Deviation
	Statistic	Statistic	Statistic	Std. Error	Statistic
Soil	.00	44.33	17.58	3.12	16.20
Root	1.00	60.00	19.52	3.42	17.75
Shoot	.00	52.00	9.44	2.02	10.51
Leaf	.00	9.00	3.41	.49	2.55
BCF	.00	11.99	1.30	.43	2.23
TF	.00	3.00	.73	.15	.77
BAC	.00	5.24	.74	.22	1.16
TFl	.00	2.25	.48	.12	.64
EFl	.00	1.12	.23	.05	.28

acetosa accumulated < 0.25 to 1.18mg/kg and the shoot < 0.25 to 0.94mg/kg. In the same study, < 0.53 to 0.94mg/kg and <00.25 to 0.90mg/kg were accumulated in the root and shoot of Urtica dioica respectively (Balabanova et al, 2015). These are lower than observed values in the present study. According to Mellem et al, (2012), A. dubius accumulated between 7.00-126.00mg/kg, 13.00-201.00mg/kg and 4.00-188.00mg/kg respectively in roots, shoots and leaves. The above values are however, higher than what is obtained from this study (Table 4a and Figure 4a).

The BCF, TF and BAC for roots, shoots and leaves

The soils to roots BCF for Amaranthus hybridus (sites 1, 3 &5), Abelmoschus esculentus, Corchorus aestuans (site 1), Laportea aestuans, Physalis angulata (site 2), Sida acuta (site 1 & 3) and Zea mays (site 3) were all > 1. The corresponding TFs were < 1 except Amaranthus hybridus that is > 1 in site 1 (Table 4a and Figure 4a). Only Amaranthus hybridus (site 1) can serve as both phytoextractor and stabilizer of As. The rest plants were only suitable for phytostabilization of As. The TFs < 1 indicates preference of these plants in storing and accumulation of As in its roots. This property of most of these plants make them not suitable for phytominig and very likely that edibles/vegetables may not accumulate above permissible level of As. Also, BCFs > 1 indicate that more As is accumulated in plants than in soil as seen among few plants (Nonglak et al, 2011; Hosman et al, 2017). The BCF in the study varied from 0.01 to 11.99. The TF from root to shoot ranged from 0.08 to 2.50. The BAC ranged from 0.07 to 5.24. The root to leaf translocation varied from 0.02 to 2.25 (Table 4a and Figure 4b). While the ability of these plants to accumulate As in root and shoot were significant in AE, COE, LA, PA,SA and ZM, the study plants also showed good degree of root to leaf translocation in CM and COA. The recorded TFs from the study were lower than 2.4 to 2.8 in A. dubius. The BCF observed was higher (on average) than the 1.0 to 5.7 BCF recorded in A. dubius (Mellem et al, 2012). The likely hood of harm from consumption of any of the edibles/vegetables due to As is remote. The capacity of the plants for phytomining of As was also not attractive. The metal intake efficiency for As varied from 9.65 to 39.19%. This value is the least among study metals (Table 4a).

Table 4b: Correlations among the variables

Variable	Soil	Root	Shoot	Leaf	BCF	TF	BAC	TFone	EFone
Soil	1	.780**	.249	.472	.096	-.480	-.045	-.488	-.269
Root	**.780****	1	.741*	.246	.642*	-.576	.468	-.676*	.051
Shoot	.249	**.741***	1	-.087	.887**	-.327	.879**	-.532	.438
Leaf	.472	.246	-.087	1	-.295	-.247	-.300	.000	.356
BCF	.096	**.642***	**.887****	-.295	1	-.420	.878**	-.570	.289
TF	-.480	-.576	-.327	-.247	-.420	1	-.274	.914**	-.025
BAC	-.045	.468	**.879****	-.300	**.878****	-.274	1	-.501	.519
TFone	-.488	**-.676***	-.532	.000	-.570	**.914****	-.501	1	-.019
EFone	-.269	.051	.438	.356	.289	-.025	.519	-.019	1

**. Correlation is significant at the 0.01 level. *. Correlation is significant at the 0.05 level.

The soil-root (r=.780), shoot-BCF (r=.887), shoot-BAC (r=.879), BCF-BAC (r=.878) and TF-TFone (r=.914) at 0.01 level have very strong relationships. These relationship shows that these pairs of variables does not discriminate in accumulation and translocation to other parts of the plants. That is, nothing within the pair that hinders metal transportation and have about the same concentrations of accumulated and translocated metals. At p<0.05, root-shoot (r=.741), root-BCF (r=.642) and root-TFone (r=-.676), strong relationships were recorded also at this level of significant. It also shows proportionality in the content of metal among pairs of variables (Table 4b).

Two clusters were extracted. Cluster one consist of TF-TFone alone. The similarity between the pair is very strong. In cluster two, , the strongest similarity was between shoot-BAC. Lesser similarity was showed between soil-root. Also, between BCF-EFone, and soil-leaf were other similarities in decreasing strength. The greatest dissimilarity was observed between root-BAC (Figure 4c). These similarities were also revealed in the correlation (Table 4b)

Cadmium (Cd).

The concentrations of Cd recorded in soils from this study were 1.53mg/kg to 16.67mg/kg (Tables 5a and b). According to Rudnick and Gao, 2003, Cd limit in uncontaminated soil is 0.10mg/kg. This limit is in contrast and lower than the values obtained from this study (Table 5a). The European commission, Luxembourg Council directive, 1986 limit of Cd in soil is 0.20mg/kg. The obtained range from the study is higher than this value (Table 5b). Based on other studies such as Papadopoulos et al, (2015); Bradford et al, (1996); the soil contents of Cd were 1.40mg/kg and 0.36mg/kg respectively. The observed range from this study is also higher than these benchmarks.

The accumulated Cd ranged from 1.00mg/kg to 18.00mg/kg in sampled roots. The shoots recorded 1.00mg/kg to 10.00mg/kg of Cd. The leaves on the other hand revealed accumulated range of 1.00mg/kg to 5.00mg/kg. These results showed that more Cd was accumulated in roots than the shoots and leaves (Table 5a and Figure 5a).This is in agreement with Ciura et al., 2005 finding that Cd is readily absorbed by roots and transported to other parts. However, this study is in contrast to their observation that Cd distribution among plants parts are regular. Balabanova et al, (2015) in their study recorded Cd 0.05 to 0.09mg/kg and 0.03 to 0.07 respectively in roots and shoots of Rumex acetosa. According to Singh et al (2010), Cd content in roots was 1.48mg/kg and 1.22mg/kg was recorded in shoots. These results are in contrast to the observed values for plant parts under investigation (Table 5a and Figure 5a). This relatively higher than unpolluted soil limit in Cd concentration may not be unconnected with the pollution from the dumps.

Table 5a: Concentration of Cd (mg/kg) in soils and plant tissues.

Scientific name	Site no.	Soil	Root	Shoot	Leaf	BCF	TF	BAC	TF_I	EF_I	ME (%) Shoot
Amaranthus hybridus *AH	1	1.53	3.00	6.00	0.00	1.96	2.00	3.92	0.00	0.00	42.42
	3	6.33	1.00	2.00	1.00	0.16	2.00	0.32	1.00	0.16	
	4	3.00	5.00	5.00	3.00	1.67	1.01	1.67	0.60	1.00	
Average values	5	11.00	2.00	1.00	2.00	0.18	0.50	0.09	1.00	0.18	
		5.47	2.75	3.50	2.00	0.99	1.38	1.50	0.87	0.45	
Amaranthus viridis AV	3	6.33	7.00	3.00	0.00	1.11	0.43	0.47	0.00	0.00	29.67
	4	3.00	1.00	0.00	1.00	0.33	0.00	0.00	1.00	0.33	
	6	16.67	0.00	1.00	0.00	0.00	0.00	0.06	0.00	0.00	
Average values	7	15.33	5.00	4.00	3.00	0.33	0.80	0.26	0.60	0.20	
		10.33	4.33	2.67	2.00	0.59	0.62	0.26	0.80	0.27	
Abelmoschus esculentus *AE	4	3.00	8.00	5.00	2.00	2.67	0.63	1.67	0.25	0.67	42.31
Average values	7	15.33	3.00	6.00	2.00	0.20	2.00	0.39	0.67	0.13	
		9.00	5.50	5.50	2.00	1.44	1.32	1.03	0.46	0.40	
Cucurbita maxima *CM	2	2.83	0.00	0.00	4.00	0.00	0.00	0.00	0.00	1.41	29.63
Average values	5	11.00	12.00	8.00	3.00	1.09	0.67	0.73	0.25	0.27	
		6.92	6.00	4.00	3.50	0.55	0.34	0.36	0.125	0.84	
Colocasia asculenta*CA	5	11.00	1.00	5.00	0.00	0.09	5.00	0.45	0.00	0.00	40.63
Average values	6	16.67	13.00	8.00	5.00	0.78	0.62	0.48	0.38	0.30	
		13.84	7.00	6.50	2.50	0.44	2.81	0.47	0.29	0.15	
Corchorus aestuans *COA	6	16.67	18.00	10.00	1.00	1.08	0.56	0.60	0.06	0.06	37.80
	2	2.83	0.00	2.00	1.00	0.00	0.00	0.71	0.00	0.35	
Average values	1	1.53	1.00	5.00	0.00	0.65	5.00	3.27	0.00	0.00	
		7.01	9.5	5.67	0.67	0.87	2.79	1.53	0.02	0.13	
Laportea aestuans *LA	1	1.53	8.00	8.00	2.00	5.23	1.00	5.23	0.25	1.31	42.57
	2	2.83	1.00	2.00	1.00	0.50	2.00	0.71	1.00	0.53	
Average values	7	15.33	12.00	10.00	3.00	0.98	0.83	0.65	0.25	0.20	
		6.56	7.00	6.67	2.00	2.24	1.28	2.20	0.50	0.62	
Physalis angulata *PA	2	2.83	4.00	1.00	2.00	1.43	0.25	0.35	0.50	0.71	21.74
Average values	6	16.67	9.00	4.00	3.00	0.54	0.44	0.24	0.33	0.18	
		9.73	6.50	2.50	2.50	0.99	0.35	0.30	0.42	0.45	
Sida acuta *SA	1	1.53	1.00	6.00	2.00	0.65	6.00	3.92	2.00	1.31	50.96
	4	3.00	5.00	3.00	1.00	1.67	0.60	1.00	0.20	0.33	
	3	6.33	0.00	0.00	1.00	0.00	0.00	0.00	0.00	0.59	
Average values		3.62	3.00	4.50	1.33	1.16	2.20	1.25	0.70	0.74	
Zea mays *ZM	3	6.33	10.00	5.00	3.00	1.58	0.50	0.79	0.30	0.47	29.55
	5	11.00	12.00	8.00	6.00	1.09	0.67	0.73	0.50	0.55	
Average values		8.67	11.00	6.50	4.50	1.34	0.59	0.76	0.40	0.51	

*Short code for plants name

Table 5b: Summary statistic of Cd in soil and plant tissues

Variable	Minimum	Maximum	Mean		Std. Deviation
	Statistic	Statistic	Statistic	Std. Error	Statistic
Soil	1.53	16.67	7.83	1.12	5.83
Root	.00	18.00	5.26	.97	5.02
Shoot	.00	10.00	4.37	.58	3.03
Leaf	.00	6.00	1.93	.30	1.54
BCF	.00	6.00	1.93	.30	1.54
TF	.00	6.00	1.24	.31	1.61
BAC	.00	5.23	1.06	.27	1.38
TFl	.00	2.00	.41	.09	.47
EFl	.00	1.41	.42	.08	.42

The concentration of Cd varied from 1.0mg/kg – 5.0mg/kg in leaves. The range of Cd from the study area is higher than 0.02mg/kg (WHO, 1996); the 1.00mg/kg (WHO/FAO, 1993) and 1.10mg/kg by Podlesakove et al's (2002) permissible limits in edibles/vegetables (Table 5c). Eating any of these plants as vegetables/edibles may not be healthy as there are no known mechanisms of ridding the body of Cd. Cadmium has been implicated in kidney disorder, bone disease, heart diseases, bronchitis, lung cancer, cancer emphysema etc (Plumlee and Ziegler, 2005)

The BCF, TF and BAC for roots, shoots and leaves

The BCF, soil to root accumulation of Cd varied from 0.16 in Amaranthus hybridus (site 6) to 5.23 in Laportea aestuans (site 1). The TF, root to shoot varied from 0.25 in Physalis angulata to 6.00 in Sida acuta (Table 5b and Figure 5b). Plants that showed BCF, TF or BAC > 1 are said to have potential for phytoextraction (Baker and Brooks, 1989; Yoon et al, 2006; Nazir et al, 2011). Therefore, Amaranthus hybridus (site 1 and 4), Abelmoschus esculentus (site 4) and Laportea aestuans (site 1) are potential species for phytoextraction of Cd from the soils. The BCF > 1, TF and BAC < 1 have also been used to evaluate phytostabilization of metals by plants (Sudmoon et al, 2015; Lorestani et al, 2011). Amaranthus viridis (site 1); Abelmoschus esculentus (site 4); Cucurbita maxima (site 5); Corchorus aestuans (site 6); Physalis angulata (site 2); Sida acuta (site 4) and Zea mays can all serve as phytostabilizers of Cd in soils (Table 5a). The BAC, that is soil to shoot accumulation ranged from 0.06 to 5.23. This also implies that these plants have potential for translocation and accumulation of Cd above-ground tissues. This indicates that Cd is easily absorbed by roots and transported to the shoots (Nazir et al, 2011). The roots to leaves TF and soil to leaf accumulation were in almost all of the plants less than < 1 except in four plants at various locations (Figure 5b). This implied inefficiency in translocation and accumulation abilities of the leaves compared to the shoots but even at that, the leaves have reasonable level of Cd. Four plants recorded EF>1, and indication of enrichment of Cd in the sampled plants. The metal uptake efficacy of Cd ranged from 21.74 to 50.96%. This value is slightly higher than that of Cr while Co ME% value is the highest (28.99 to 89.08%).

Table 5c: Correlations among variables									
Variable	Soil	Root	Shoot	Leaf	BCF	TF	BAC	TFone	EFone
Soil	1	.179	-.002	.636*	-.477	-.176	-.799**	-.392	-.578
Root	.179	1	.720*	.482	.104	-.263	-.293	-.832**	.176
Shoot	-.002	**.720***	1	.453	.340	.151	.167	-.541	.397
Leaf	**.636***	.482	.453	1	-.226	-.213	-.560	-.304	.066
BCF	-.477	.104	.340	-.226	1	-.205	.580	-.005	.486
TF	-.176	-.263	.151	-.213	-.205	1	.559	.147	-.120
BAC	**-.799****	-.293	.167	-.560	.580	.559	1	.363	.390
TFone	-.392	**-.832****	-.541	-.304	-.005	.147	.363	1	.237
EFone	-.578	.176	.397	.066	.486	-.120	.390	.237	1
*. Correlation is significant at the 0.05 level. **. Correlation is significant at the 0.01 level.									

At the significant level of 0.01, only soil-BAC (r=-.799) and root-TFone (r=-.832) recorded very strong correlations. This negative correlation indicates active Cd accumulation but reduction in biomass due to soil contamination and low plant tolerance to Cd (Poniedzialek et al.,2010) At P< 0.05 level, soil-leaf (r=.636), and root-shoot(r=.720) displayed strong correlation. Pairs of variables with strong correlation reflected unhindered ability to proportionally accumulate and translocate as much metal from soil-leaf and from root to shoot. This is irrespective of whether Cd is low in soil (Table 5c).

Two clusters were revealed. Cluster one is an association between root-shoot, soil-leaf and soil-root. The strongest similarity in the cluster was between root-shoot, followed by soil-leaf and lastly soil-root. In cluster two, BCF-BAC and BCF-EFone were extracted. At a greater distance, TFone and TF were linked to this cluster. From the two clusters, root-shoot, soil-leaf, BCF-BAC and BCF-EFone, the strength of similarities displayed decreases in this order. Root-shoot showed uninhibited mobility of Cd. Soil-leaf also showed a lesser mobility from soil-leaf. Followed by these two was BCF-BAC displaying good degree of Cd mobility (Figure 5c).

Conclusively, this investigation has shown that Co has three hyperaccumulator plants. As has no hyperaccumulator and phytoextractor but phytostabilizers. Cd has only Sida acuta as phytoextractor at site 3 and COA and LA as phytostabilizers. AH (sites 1 and 4), AE, LA (site 1) were all phytoextractors of Cd. Few other plants were also phytostabilizers of Cd. Cr, Co and Cd can be phytomined from some of the plants while prospect for mining As from the plants is limited. Edible parts/vegetables from some of the plants may have excess of Cr, Co and Cd. It is strongly recommended that these edibles/ vegetables should not be consumed by humans. The metal uptake efficacy (%) were in the order Co (28.99 to 89.08) > Cd (21.74 to 50.96) >Cr (22.90 to 49.06) > and As (9.65 to 39.19).

Declarations

Acknowledgment: The authors thanked the field and laboratory teams for their expertise. All the resource persons that corrected the grammatical errors are highly appreciated.

References

1. Alan, J.M. Baker, S. P. McGrath, Roger D. Reeves and J.A.C. Smith (2000). Metal hyperaccumulator plants: A review of the ecology and physiology of a biological resource for phytoremediation of metal polluted soils. *CRC Press*, L.L.C.
2. Allen, S.E; (1989). Chemical analysis of ecological materials. *Blackwell Scientific publications, Oxford*.
3. Ahmad Anwar; Rumana Ghufran; A.W. Zularisam (2010). Phytosequestration of metals in selected plants growing on a contaminated Okhla industrial area, Okhla, New Delhi, India. *Water Air Soil pollution.*
4. Baker A.J.M and Brooks, R.R., (1989). Terrestrial higher plants which hyperaccumulate metallic elements- a review of their distribution, ecology and phytochemistry. *Biorecovery,* 1,pp. 81-126.
5. Bell, P.E; Xie, B; Higby, J.R; Aminha, N; (2000). Digestion of NIST Peach leaves using sealed vessels and inexpensive microwave ovens, commun. *Soil sci. plan*; 31: 1897-1903.
6. Balabanova Biljana; Trajce Stafilov and Katerina Baceva (2015). Bioavailability and bioaccumulation characterization of essential and heavy metal, contents in R. acetosa, S. oleracea and U. dioica from Copper polluted and referent areas. *Journal of Environmental Health Science and Engineering* Vol. 13(2). pp.1-13

7. Ng.Chuck Chuan, Amru Nasrulbaq Boyce, Md Motio Rahman, Mhd Radzi Abas, Noor Zalina Mahmood (2018). Phytoevaluation of Cd-Pb using tropical plants in soil-Leachate conditions. *Air, soil and water research*, 11:1-9.
8. Baroni F.; A. Boscagli, G. Protano, F: Riccobono (2000). Trace metals in the environment. *Science Direct.* 3: 341-361.
9. Bradford, G.R.; A.C. Change; A.L Page; D. Bakhtar; J.A Frampton; H. Wright (1996).
10. Background concentrations of Trace and major elements in California soils, 1-32.
11. Ciura, J, Poniedzialek, M, Sekara, A, Jedrszczyk, E (2005). The possibility of using crops
12. as metal phytoremendiants. *Polish Journal of environmental studies*, vol.14(1), 17-22
13. Ghosh M. and Singh S.P., (2005). A review on phytoremediation of heavy metals and
14. utilization of it's by products. *Asian Journal of energy and environment,* Vol. 6,pp. 214-231.
15. Huu, H.H.,Rudy, S and An Van Damme (2010). Distribution and contamination status of heavy metals in estuarine sediments near Cau Ong habour, Ha Long Bay, *Vietnam Geology*. 23(2):23-46.
16. Iya, Naseer Inuwa Durumin; Zaini Bin Assim; Isa Bin Ipor; Ajoke Omonrinoye Omolayo; Isaac John Umaru; Binta Hadi Jume (2018). Accumulation and translocation of heavy meatls by Acalypha wilkesiana parts in the phytoextraction of contaminated soil. *Indonesia J. chemistry*, 18(3): 503-513.
17. Mellem John, J.; Himansu Baijnath and Bhart Odhav (2012). Bioaccumulation of Cr, Hg, As, Pb, Cu, and Ni with the ability for hyperaccumulation by Amaranthus dubius. *African Journal of Agricultural Research* Vol. 7(4). Pp. 591-596.
18. Kabata-Pendias A, Pendias, H (1992). Trace elements in soils and plants. *Boca Raton*, FL: CRC Inc.
19. Kabata-Pendias, A and H. Pendias (2001). Trace elements in soils and plants, 3rd Edition. *Boca Raton*: CRC Press.
20. Lago-Vila, M.; D. Arenas-Lago; A. Rodriquez-Seijo; M.L Andrade Couce; F.A Vega (2015). Cobalt, chromium and nickel contents in soils and plants from a serpentinite quarry. *Solid Earth*, 6: 323-335.
21. Lyons, P.C., Curtis, A.P., Bostick, N.H., Fletcher, J.D., Dulong, F.T., Brown, F.W., Brown, Z.A., Krasnow, M.R and Romankiw, L.A (1989). Chemistry and origin of minor and trace elements in Vitrinite concentrates from a rank series from the eastern United States, England and Australia. *International Journal of Coal Geology*, 13:481-527.
22. Mediolla, L.L., Domingues, M.C.D and Sandoval, M.R.G (2008).Environmental assessment of an active tailing piles in the state of Mexico (Central Mexico). *Res. Jes. Environ. Sci.* 2(3):197-208.
23. Mongkhonsin, B; Nakbanpote, W., Nakai, I; Hokura, A; Jear-anaikoon, N. (2011). Distribution and speciation of chromium accumulated in Gynura pseudochina (L.) DC, *Environ. Exp. Bot.* 74:56-64.
24. Mganga, Nyatwere D. (2014). The potential of Bioaccumulation and Translocation of heavy metals in plant species growing around the tailing Dam in Tanzania. *International Journal of Science and Technology*, 3(10): 690-697.
25. Nazir Ashfaq, Riffat Naseem Malik, Muhamamd Ajaib, Nasrullah Khan and Muhammad Faheem Siddiqui (2011). Hyperaccumulators of heavy metals of industrial areas of Islamabad and Rawalpindi. *Pakistan Journal of Botany* Vol 43(4), PP.1923-1933.
26. Nonglak Rungruang, Sandhya Babel, Preeda Parkpian (2011). Screening of potential hyperaccumulator for Cadmium from contaminated soil. *Desalination and water treatment* vol. 32. PP. 19-26
27. Opaluwa, O.D; Aremu, M.O; Ogbo, L.O; Abiola, K.A; Odiba, I.E; Abubakar, M.M; Nweze, N.O. (2012). Heavy metal concentrations in soils, plant leaves and crops grown around dump sites in Lafia metropolis, Nasarawa State Nigeria. *Advances in Applied Science Research*, 3 (2): 780 – 784.
28. Papadopoulos C.; C. Gekaa; F. Pavloudakis; C. Roumpos; S. Andreadou (2015). Evaluation of the soil quality on the reclaimed lignite mine land in West Macedonia, Greece. Procedia Earth and Planetary Science, *Science Direct*. 15: 928-932.
29. Plumlee, G.S and Ziegler, T.L (2005). The medical geochemistry of dusts, soils and other earth materials. *US Geological Society, Denver*, CO, USA.
30. Poniedzialek, M. Sekara, A; Jedrszczyk, E and Ciura, J (2010). Phytoremediation efficiency of crop plants in removing Cadmium, Lead and Zinc from soil. *Folia Horticulturea,* 22(2), 25-31
31. Rangnekar, S.S; Sahu, S.K; Pandit, G.G; Gaikwad, V.B (2013). Accumulation and translocation of Nickel and Cobalt in nutritionally important Indian vegetables grown in artificially contaminated soils of Mumbai, India. *Research Journal of Agriculture and Forestry Sciences,* 1 (10): 15-21.
32. Singh Ramesh; D.P. Singh; Narendra Kumar; S.K Bhargava; S.C. Barman (2010). Accumulation and translocation of heavy metals in soil and plants from fly ash contaminated area. *Journal of Environmental Biology*, 31: 421-430.
33. Sinka, T (2018). Integrated phytomining and ethanol production in the Zambian copperbelt to minimize mine decontamination costs and environmental and social impacts: a review. *Journal of Southern Institute of mining and metallurgy*, vol.118 (6), 1-14
34. Suman J.O.U; Jitka, V. and Tomas, M (2018). Phytoextraction of heavy metals: A promising tool for clean-up of polluted environment. *Front plant Science*. vol.9,1-29.
35. Tappero, R; Peltier, E; Grafe, M; Heidel, K; Ginder – Vogel, M; Livi, K; Rivers, M; Marcus, M; Chaney, R; Sparks, D; (2007). Hyperaccumulator Alyssum murale relies on a different metal storage mechanism for Cobalt than for Nickel, *New phytol,* 175:641-654.
36. Verbruggen, N; Hermans, C; Schat, H; (2009). Molecular mechanisms of metal hyperaccumulation in plants, *New phytol,* 181:759-776.
37. Violante, A., Cozzoolino, V., Perelomov, L., Caporale, A.G and Pigna, M (2010).Mobility and bioavailability of heavy metals and metalloids in soil environments. *J. Soil Sci. Plant Nutr.*10 (3):268-292.
38. WHO, (1976). Critical levels of different metal ions in edible portion of vegetables

39. WHO/FAO, 1993. Guidelines for metals in food and vegetables.
40. Yoon Joonki, Xinde Ceo, Qixing Zhou, Len Q. Ma (2006). Accumulation of Pb, Cu, and Zn in native plants growing on a contaminated Florida site. *Science of the total environment* vol. 368.pp.456-464.

Figures

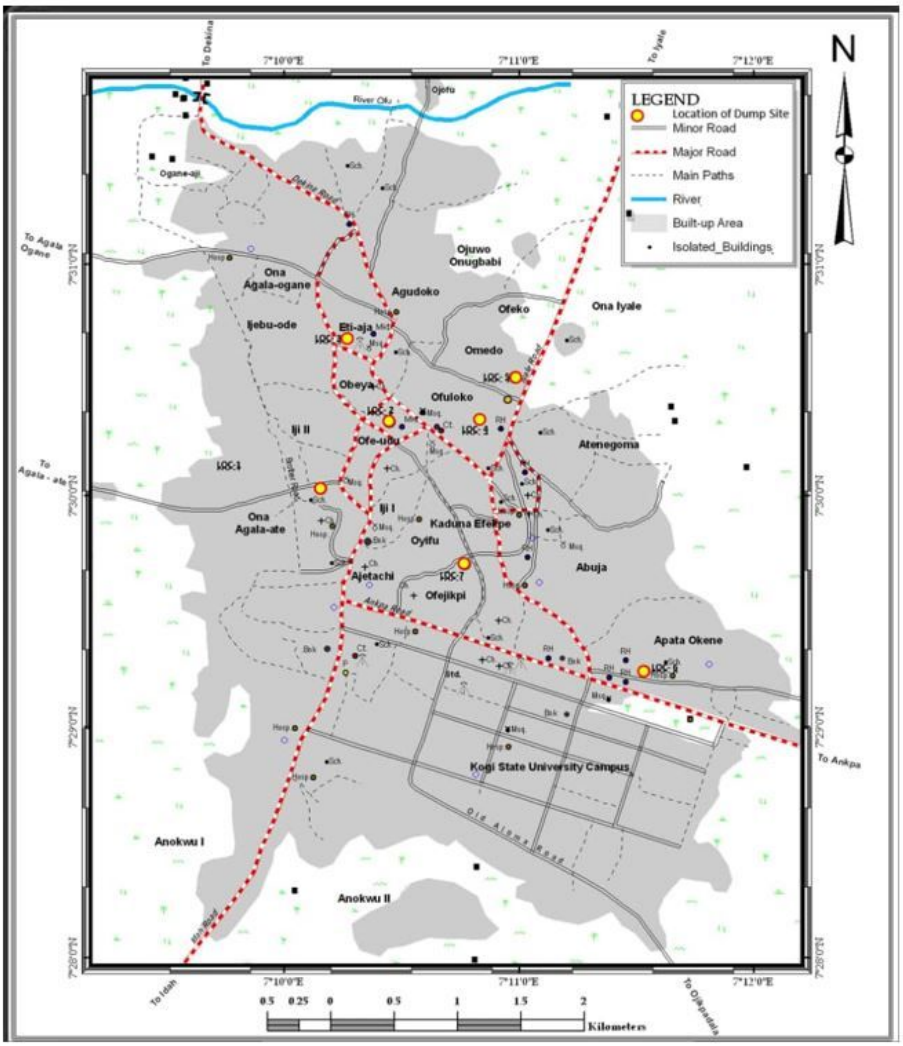

Figure 1

Sample location map of study area (after Ameh, et al., 2019).

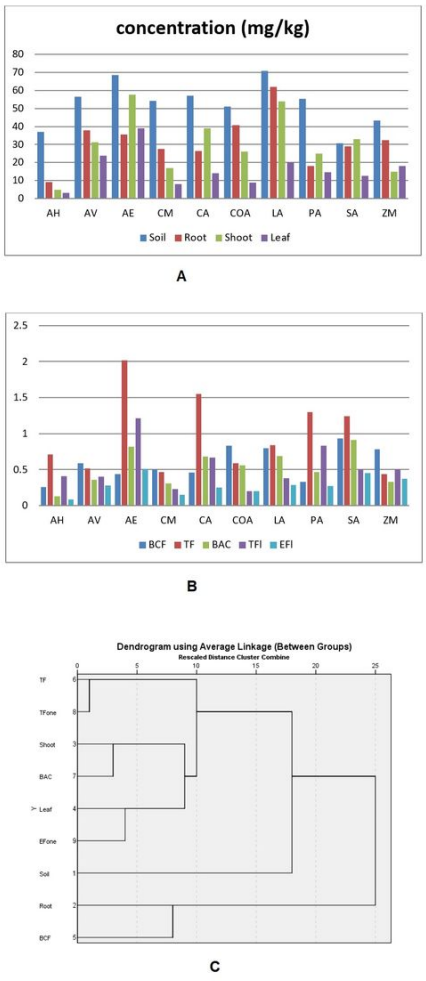

Figure 2

a: Average concentration (mg/kg) of Cr in soil and plant tissues b: Average Cr variations in plant tissues c: Cluster analysis of variables

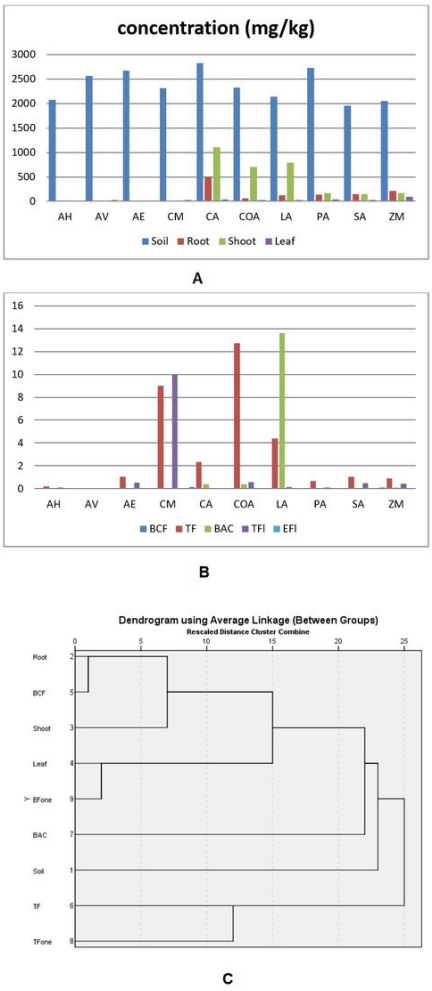

Figure 3

Average Co concentration (mg/kg) in soil and plant tissues Average Co variations in plant tissues Cluster analysis of variables.

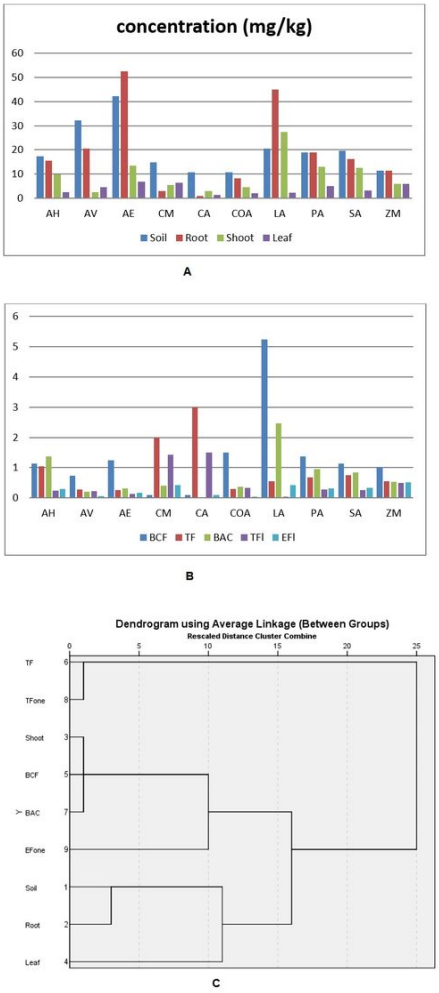

Figure 4

Average concentration (mg/kg) of As in soil and plant tissues Average As variation in plant tissues Cluster analysis of variables

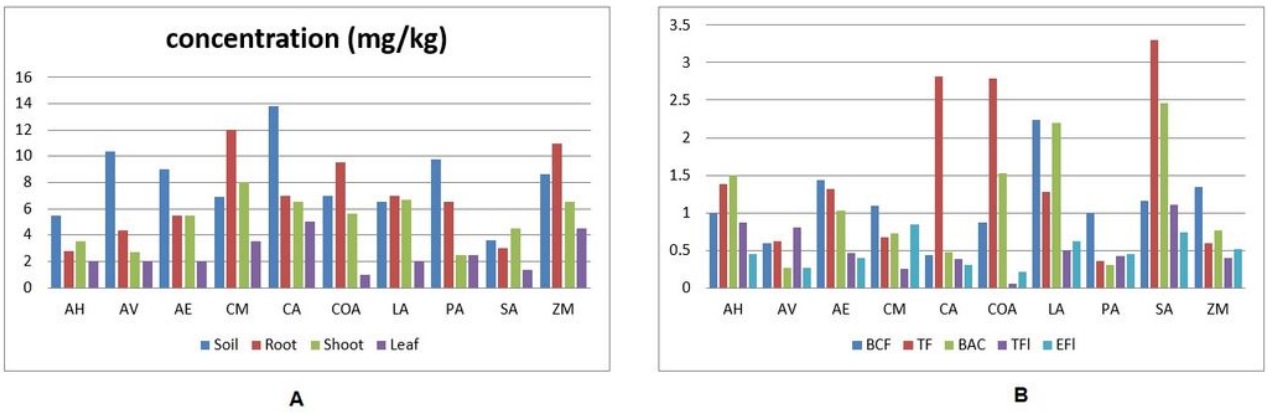

Figure 5

Average Cd concentration (mg/kg) in soil and plant tissues Average Cd variation in plant tissues

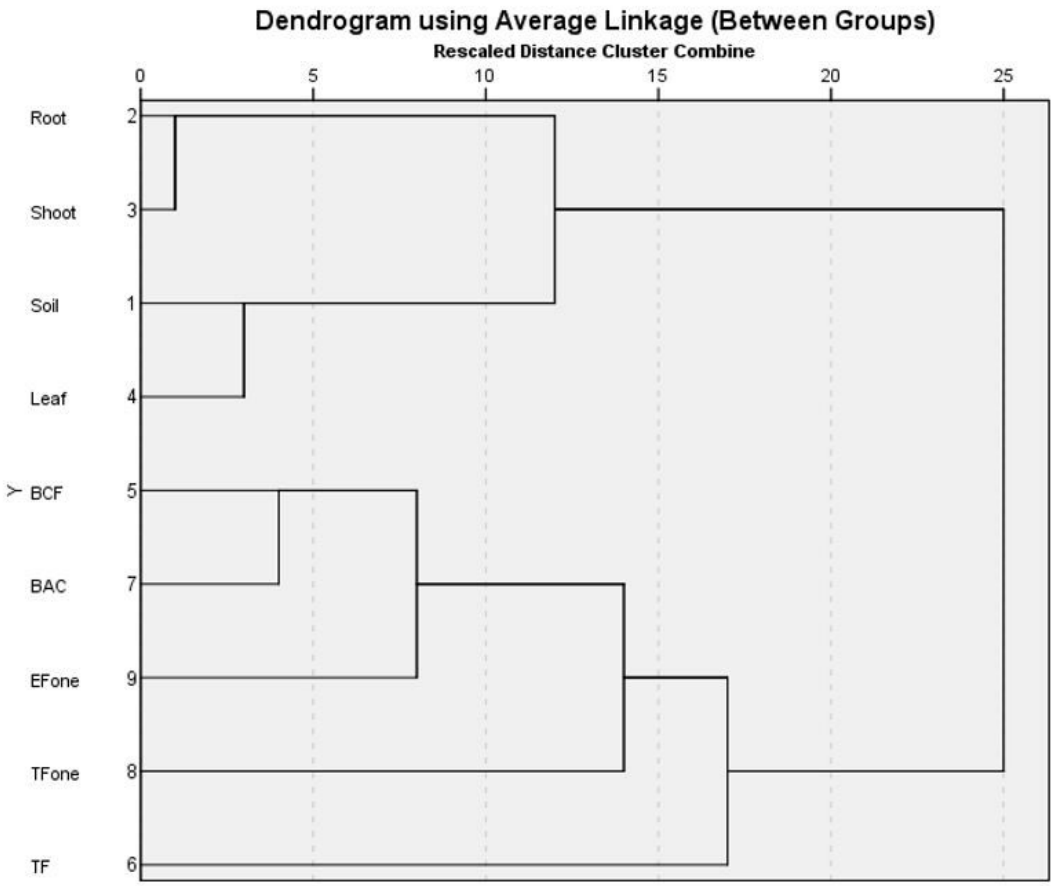

Figure 6

Cluster analysis of the variables