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Metal uptake efficacy and phytoremediation potential of plants grown around soil dumpsites in Anyigba, Kogi State, Nigeria

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ABSTRACT

Plant's accumulation and translocation potentials were investigated for phytoremediation purposes, recovery of metals, potential for edibles/vegetables to cause harm to humans. Plant and soil were collected, prepared, digested in mixturesof H_2O_2-HNO_3 and $Li_2B_4O_7$.$LiBO_2$ for plants and soils respectively. The concentrations of Co, Cd, Cr, and As, accumulation and translocation were determined. Data were evaluated using bioconcentration (BCF), translocation factor (TF), bioaccumulation coefficient (BAC), metal uptake efficiency (ME%), multivariate analyses to establish hyperaccumulators, phytoextractors, phytostabilizers, source of metals and theirtoxicity. Analysis of variance (ANOVA) showed data were significant at $p < 0.05$. Correlation,factor and cluster analyses were employed to understand the accumulation and translocation of metals in soils and plants tissues.From this study, *Colocasia asculenta, Corchorus aestuans and Laportea aestuans* were hyperaccumulators of Co. Arsenic had only phytostabilizers. COA and LA were phytostabilizers and *Sida acuta* was phytoextractorof Cd respectively. Chromium, Co and Cd could be phytomined from some of the plants. Vegetables/edibles values in shoots and leaves were above permissible levels for Cr, Co and Cd. Only *Sida acuta* was not edible.Metal uptake efficacy (%) order were 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).

Keywords: reservoir, uptake, native, phytomined, factor

1.0 INTRODUCTION

1.1 Introduction

Trace metals occur naturally in all soils in low concentrations. However, the level of these metals have greatly increased due to human activities such as waste (domestic and municipal), textile, battery and auto workshops, mining, agriculture etc (Ameh & Aina, 2020;Ameh *et al*.,2021; Yuan, *et al*.,2022). At high concentrations, these toxic metals 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 easilytranslocatedfrom plants to animals and 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 can remove metals from soil in large amount. Valuable metals can also be recovered economically and those with potential to cause harm are avoided. Over time, land is made available for other socio-economic uses once the pollution has been reduced to minimal and acceptable levels

The objectives of this study were therefore, to (i) identify and determine metal concentrations in plants and edibles/vegetables in study soil (ii) compare metal concentrations in soil and plant 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 potentialand harmful health effects on humans.

2.0 MATERIALS AND METHODS

2.1 Materials

In the couse of this research work, some of the materials used on the field were topo maps, Global

Positioning System (GPS), hand auger, ruler, polyethelene bage etc. In the Laboratory, acids were used for samplee digestions, petrish dishes, oven were used for sample extraction.

2.2 Methods

2.2.1 Plant and soil sample collections

Ten plant species were collected. Plant samples collected were representative of available plant species. 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

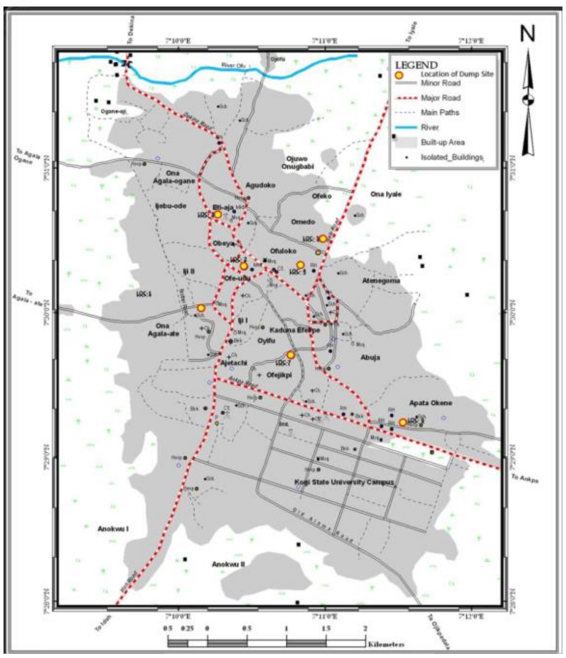

Figure 1: Sample Location Map of Study Area (after Ameh, *et al*., 2019).

Soil samples were collected from the rhizospheres (0cm-20cm depths) at each previously sampled plant points. The samples were screened for pebbles, dirt, sticks etc. Equal subsamples of the soil were homogenized thoroughly and a composite sample taken (Baker and Brooks, 1989; Yuan, *et al*.,2022). The samples were oven-dried at 105^{o}C for complete moisture removal and passed through 2mm sieve using a magnetic sieve shaker to collect the fine fraction for further analysis.

plastic hand trowel to dig the soil and were gently removed to ensure no part was lost. 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 self-sealing and well- labeled plastic bags. Plant materials were oven-dried for 72hours at 70^{o}C to obtain a constant dry matter yield, crushed and homogenized in a mortar using pestle and were stored in sealed polyethylene bags for analysis (Gouri Das & Ashwani Kuma, 2022).

2.2.2 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. This was continued till a minimal clear layer of acid was obtained. After cooling, the content was filtered through a Whatman filter paper number 41. Final volume of 25ml was made in a clean volumetric flask using 0.25% of HNO_3 (Ameh *et al*.,2021).

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 $Li_2B_4O_7$-$LiBO_2$ flux (50/50 w/w) and 1.0g of LiI in a platinum crucible (Yoon *etal*, 2006). The mixture 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 filtrates of both plant and soil were analyzed for metal content using EDX3600B X-ray Fluorescence Spectrometer (Skyray Instruments Inc., a 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 were 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 (Ameh *et al*.,2019).

2.2.3 Quality control/Quality assurance

Each plant 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 (Ameh *et al*.,2021). 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.

2.2.4 Experimental Interventions

Bioconcentration Faction (BCF): was calculated as metal concentration in the plant root, shoot and leaves/metal concentration in soil (Suman, 2018; Gouri Das & Ashwani Kuma, 2022)……..(1)

Translocation Factor (TF): was calculated as the ratio of metal concentrations in plant's shoot and leaves to concentration of metal in corresponding root (Brooks and Baker, 1989; Yuan, *et al*.,2022)……(2).

Plants with higher translocation factor have greater accumulation ability. Translocation is useful in monitoring metal contamination and selection of metal accumulator or tolerance species (Ng. *et al*., 2018). This index also shows which plants can be phytomined and which can harm humans when consumed.

Bioaccumulation Coefficient (BAC): The BAC was 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)…….(3)

Enrichment factor (EF1): was calculated as the ratio of plants leaf concentration to soil concentration (Ameh & Aina, 2020)……………(4)

Metal uptake efficacy (%): was the ratio of metal accumulated in shoot/ total metal concentration removed from the soil media ×100 (Ng *et a*l., 2018; Fang *et a*l., 2021)……(5)

The analyses of variance and factor were performed using SPPS version 20. All the data generated by ANOVA in this study were significant at $p<0.05$. (Ameh *et al*., 2021).

3.0 RESULTS AND DISCUSSION

3.1 Chromium (Cr)

Cr concentrations in soils from the waste dumps in thestudy area ranged from19.00in 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 limitof 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 the 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; Jyotsna Kaushal & Pooja Mahajan, 2022). The concentration 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. Compared to the soil concentrations of Cr in the 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). In another study, 19.63 ± 1.79mg/kg and 29.49 ± 3.40mg/kg were accumulated in the roots of *Festucarubra L.* and *Juncussp.L* respectively (Lago-Vila *etal*, 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	42.30	5.00	2.00	3.00	0.12	0.0	0.04	0.60	0.07	27.54
	3	30.30	2.00	3.00	1.00	0.07	1.0	0.10	0.50	0.03	
	4	19.00	9.00	4.00	2.00	0.47	0.4	0.21	0.22	0.11	
	5	56.00	21.00	10.00	7.00	0.38	0.8	0.18	0.33	0.13	
Average values		36.20	9.25	4.75	3.25	0.26	0.71	0.13	0.41	0.09	
Amaranthusviridis *AV	3	30.30	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	58.30	34.00	20.00	12.0	0.58	0.59	0.34	0.35	0.21	
	7	1180	95.00	100.00	56.0	0.81	1.05	0.85	0.59	0.48	
Average values		56.42	38.00	31.25	23.67	0.59	0.52	0.36	0.40	0.28	

Scientific name	Site no.	Soil	Root	Shoot	Leaf	BCF	TF	BAC	TF_l	EF_l	ME% Shoot
Abelmoschusesculentus*	4	19.00	6.00	15.00	8.00	0.32	2.50	0.79	1.33	0.42	43.56
AE	7	1180	65.00	100.00	70.0	0.55	1.54	0.85	1.08	0.59	
Average values		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	
Colocasiaasculenta	5	56.00	17.00	30.00	18.00	0.30	1.76	0.54	1.06	0.32	49.06
*CA	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	
Corchorusaestuans	6	58.33	30.00	10.00	2.00	0.51	0.33	0.17	0.07	0.03	34.36
*COA	2	52.33	42.00	19.00	7.00	0.80	0.45	0.36	0.17	0.13	
	1	42.33	50.00	49.00	18.00	1.18	0.90	1.16	0.36	0.43	
Average values		51.00	40.67	26.00	9.00	0.83	0.59	0.56	0.20	0.20	
Laporteaaestuans	1	42.33	28.00	11.00	4.00	0.66	0.39	0.26	0.14	0.09	39.71
*LA	2	52.33	38.00	49.00	30.00	0.73	1.29	0.94	0.79	0.57	
	7	118.0	120.00	102.00	26.00	1.02	0.85	0.86	0.22	0.22	
Average values		70.89	62.00	54.00	20.00	0.80	0.84	0.69	0.38	0.29	
Physalisangulata	2	52.33	22.00	38.00	16.00	0.42	1.73	0.73	0.73	0.31	43.48
*PA	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	
Sidaacuta	1	42.33	40.00	80.00	13.00	0.95	2.00	1.89	0.33	0.31	44.19
*SA	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	
		30.55	29.00	33.00	12.67	0.93	1.24	0.91	0.50	0.45	
Average values											
Zea mays	3	30.33	26.00	8.00	6.00	0.86	0.31	0.26	0.23	0.20	22.90
*ZM	5	56.00	39.00	22.00	30.00	0.70	0.56	0.39	0.77	0.54	
		43.17	32.50	15.00	18.00	0.78	0.44	0.33	0.50	0.37	
Average values											

*Short code for plants name

Table 1b: 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	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	1.10

According to Iya *et al* (2018), the highest accumulation of Cr in root of *A. wilkesiana* was 101.23 ± 2.92mg/kg (see Table1). 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 (see 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 values were both lower than the obtained range from thisarea.This is an indication of higher accumulation and translocation of Cr to the shoots in study area.Hyperaccumulators of Cr must concentrate upto 0.10% of Cr with TF or EF>1 (Verbruggen *etal*, 2009). Baker and Brookes, 1989; Lorestani *et al*., 2011 considered plants as hyperaccumulator of Cr based on, (i) that the 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) TFor EF>1 and (iv) that the 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 were generally lower compared with the stem and root (see Table 1). 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. 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 (see Table 1a). This limit suggested that edibles/vegetables among sampled plants have excess of Cr and may not be safe for human intake. The Cr concentrations in leaves were high, as only three locations recorded <1.30mg/kg. This implied high Cr in most leaves. Chromium in the body can result in acute kidney failure, long term risk for lung cancer, contact dermatitis among others (Ali, 2018).

3.1.1 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 were observed (see Table 1a). This showed 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 stated that translocation of Cr from roots to shoots was extremely limited. The BCF ranged from 0.07 to 1.18in thestudy area. In *R. acetosa*, BCF range of 0.15 to 0.24 was observed. In *U. dioica*, BCF varied from 0.02 to 0.04 (Balabanova *etal;* 2015). The onlyphytoextractor of Cr in the area was *Sida acuta* in site 3 and a good plant for phytomining. Plants with BCF > 1, TF or EF< 1 were suitable for phytostabilization of Cr. Therefore, COE (site 1) and LA were phytostabilizers of Cr. The TFvalues for Cr were slightly higher in most sampled points than the BCF. Contrary to the Cr soil-root accumulation, the plants under study tolerated and accumulated Cr from root to the shoot. This is contrary to Jyotsna Kaushal & Pooja Mahajan 2022, where accumulation in roots were 100-fold higher than in shoots. This tolerance and ability to accumulate Cr in shoot showed that the plants have potential for phytomining (Sinka, 2018). The TF of Cr from the study ranged from 0.08 to 2.50. This indicated relative ability to accumulate Cr in above ground tissues. Mellem *etal*., (2012) observed TF range of 0.5 to 1.1 for Cr. Also Suman, (2018), recorded TF value of 0.73 for Cr in a similar study. The BAC were mostly< 1 in most points. These suggested 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 (see Table 1).

3.2 Cobalt (Co)

Co concentrations in soils ranged from 1536.67mg/kg in site 1 to 3240.47mg/kg in site 6 (see Table 2). Coin uncontaminated soil is 7.00mg/kg (Kabata- Pendias, 2001); 14.90mg/kg (Bradford *et al*., 1996) and 40.00mg/kg (Papadopoulos *etal*, 2015). The concentrations cited are below the study areaconcentrations. This suggestedsoil pollution from the wastes dump in the area (see Table 2 amd 1b). 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 2). 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 (see Table 2).This showed that Co was readily absorbed by roots and translocated to the shoot. Sometimes Co could be accumulated higher in shoots even though its concentration in soil is lower. The highest Co concentration in leaf (152.00mg/kg) was recorded in *Zea mays* and *Amaranthus hybridus* recorded theleast value of 0.00mg/kg. This was possible because *Zea mays* grew rapidly and had higher biomass production (Suman *et al*., 2018). The permissible value of Co invegetablesis 0.02mg/kg (WHO,1996) and 6.00mg/kg (Podlesakova et al.,2002). Both limits are lower than the average Co concentration in vegetables from the area.All the values recorded in the leaves were higher than the permissible level except at four locations (see Table 2). Food safety with respect to Co contents in vegetable intake require attention, though Co is an essential nutrient for both plants and humans (see Table 2 & 1b). Co has been implicated for causing cardiomyopathy, polycythemia and cancer (Ali, 2018).

Table 2: 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
Amaranthushybridus *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	
	5	2415.33	21.00	14.00	2.00	0.01	0.67	0.01	0.10	0.00	
Average values		2072.75	8.25	5.50	4.25	0.00	0.19	0.00	0.13	0.00	
Amaranthusviridis *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	
	7	2687.00	0.00	0.00	9.00	0.00	0.00	0.00	0.00	0.00	
Average values		2566.67	0.00	12.25	30.25	0.00	0.00	0.01	0.00	0.00	
Abelmoschusesculentus *AE	4	2654.00	15.00	32.00	16.00	0.01	2.13	0.01	1.07	0.01	51.52
	7	2687.00	0.00	2.00	1.00	0.00	0.00	0.00	0.00	0.00	
Average values		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	
		2309.17	1.00	20.00	24.00	0.00	9.00	0.01	10.00	0.01	
Average values											
Colocasiaasculenta *CA	5	2415.33	403.00	1200.00	45.00	0.17	2.98	0.50	0.11	0.02	66.95
	6	3240.67	612.00	1020.00	36.00	0.19	1.67	0.31	0.06	0.01	
Average values		2828.00	507.50	1110.00	40.50	0.18	2.33	0.41	0.09	0.02	
Corchorusaestuans *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	
	1	1536.67	43.00	1052.00	40.00	0.03	24.47	0.68	0.93	0.03	
Average values		2326.78	58.67	707.33	28.00	0.03	12.72	0.39	0.57	0.02	
Laporteaaestuans *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	
	7	2687.00	83.00	1075.00	38.00	0.03	12.95	0.40	0.46	0.01	
Average values		2142.22	127.67	786.0	26.67	0.06	4.39	0.41	0.18	0.01	
Physalisangulata *PA	2	2203.00	273.00	322.00	65.00	0.11	1.36	0.15	0.27	0.03	48.47
	6	3240.67	0.00	10.00	15.00	0.00	0.00	0.00	0.00	0.00	
Average values		2721.84	136.50	166.00	40.00	0.06	0.68	0.08	0.14	0.02	
Sidaacuta *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

From the study, *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 (see Table 2). 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 leave's 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.The CA, COA, and AE,CM,LA,PA,SA and ZM (one site each) that accumulated and translocated more Co to above parts were plants that were suitable candidates for phytoremediation and also have the potential for phytomining of Co. Where this metal is in excess in vegetables/edibles and are taken by man, it can also be 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 *etal*, 2018). Also, 5.17 to 8.17mg/kg and 0.92 to 1.10mg/kg concentrationswere observed in shoots of *Festucarubra L*. and *Juncussp.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 observations ,made by Iya *et al*., (2018).

3.2.1 The BCF, TF, BAC for both shoots and leaves

The BCF for Co were all < 1 in the study area. This suggested limited accumulation of Co by the roots from the soil. An indication that the roots were excluders of Co (see Table 2). Interestingly too, the translocation factors for Co were very high in some locations. Translocation factor ranged from 0.23 in *Laportea aestuans* to as high as 24.47 in *Corchorus aestuans* (see Table 2). The high TFcould suggest that thesetwo plants and few others at one location eachmay besuitable source for mining of Co. The BAC for plants were all < 1. The root to leaf translocations were> 1 (in three sampled plants at three locations). Soils to leaf accumulations were all < 1(see Table 2). These observations showed high translocation but low accumulation in the respective tissues. The TFs in the study area were contrary to TFs of < 1 recorded for *Festuca*and *Juncus*. The current results werealso in contrast to BCF recorded in roots of *Festuca and Juncus* which were 1. The BAC for shoots agreed with the < 1 values obtained for *Juncus sp. L* (Lago-Vila *etal*, 2015). From this study, no plant was suitable as phytoextractor and phytostabilizer of Co but high values of TFs were recorded in some plant's shoot. Metal uptake for Co was highest among the metals under study. ME for Co ranged from 28.99 to 89.08%.

3.3 Arsenic (As)

The As in soil 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. The background concentration of major and trace elements in California soils is 0.80mg/kg (Bradford etal, 1996). The range observed from this study clearly showed elevated levels of As due to the waste dumps (see Table 3 & 1b). 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* (see Table 3). The As accumulated in shoot varied from 1.00mg/kg to 52.00mg/kg. In leaves, As recorded was between 1.00mg/kg to 9.00mg/kg. The average range in leaves was higher than 0.20mg/kg limit of WHO,1996 and 2.00mg/kg by Podlesakova *et al.*,2002 (see Table 3). The As is a known cause of systemic hypertension, anemia, liver necrosis, kidney failure and acute leukemia (Ali, 2018). Excess of it in edibles/vegetables may be harmful to humans. Generally, the As accumulated were highest in roots, followed by shoot and lastly the leaves (see Table 3).

Table 3: 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
Amaranthushybridus	1	2.67	4.00	10.00	2.00	1.50	2.50	3.75	0.50	0.75	35.14
*AH	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	
	5	10.67	12.00	10.00	3.00	1.12	0.83	0.94	0.25	0.28	
Average values		17.42	15.50	9.75	2.50	1.14	1.04	1.37	0.24	0.30	
Amaranthusviridis	3	12.00	7.00	4.00	1.00	0.58	0.57	0.33	0.14	0.08	9.65
*AV	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	
	7	40.00	29.00	0.00	2.00	0.73	0.00	0.00	0.07	0.05	
Average values		32.11	20.50	2.67	4.50	0.74	0.27	0.20	0.23	0.06	
Abelmoschusesculentu	4	44.33	60.00	15.00	6.00	1.35	0.25	0.34	0.10	0.14	18.49
s *AE	7	40.00	45.00	12.00	8.00	1.13	0.27	0.30	0.18	0.20	
Average values		42.17	52.50	13.50	7.00	1.24	0.26	0.32	0.14	0.17	
Cucurbita maxima	2	19.00	4.00	6.00	9.00	0..01	1.50	0.32	2.25	0.47	36.67
*CM	5	10.67	2.00	5.00	4.00	0.19	2.50	0.47	2.00	0.37	
Average values		14.84	3.00	5.50	6.50	0.10	2.00	0.40	1.42	0.42	
Colocasiaasculenta	5	10.67	1.00	0.00	1.00	0.09	0.00	0.00	1.00	0.09	37.50
*CA	6	0.00	1.00	3.00	2.00	0.00	3.00	0.00	2.00	0.00	
Average values		10.67	1.00	1.50	1.50	0.05	1.50	0.00	1.50	0.05	
Corchorusaestuans	6	0.00	5.00	1.00	3.00	0.00	0.20	0.00	0.60	0.00	31.78
*COA	2	19.00	14.00	7.00	1.00	0.74	0.50	0.37	0.07	0.05	
	1	2.67	6.00	1.00	0.00	2.25	0.17	0.37	0.00	0.00	
Average values		10.84	8.33	4.50	1.33	1.50	0.29	0.25	0.34	0.02	
Laporteaaestuans	1	2.67	32.00	14.00	3.00	11.99	0.44	5.24	0.09	1.12	36.62
*LA	2	19.00	43.00	16.00	1.00	2.26	0.37	0.84	0.02	0.05	
	7	40.00	60.00	52.00	3.00	1.50	0.87	1.30	0.05	0.08	
Average values		20.56	45.00	27.33	2.30	5.25	0.56	2.46	0.05	0.42	
Physalisangulate *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	
Sidaacuta *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	

Scientific name	Site no.	Soil	Root	Shoot	Leaf	BCF	TF	BAC	TF_l	EF_l	ME (%) Shoot
	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

In another study, the roots of *Rumex 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/kgand <00.25 to 0.90mg/kg were accumulated in the root and shoot of *Urticadioica* respectively (Balabanova *etal*, 2015). These are lower than the observed values in the present study. According to Mellem *etal*, (2012), *A. dubius* accumulated 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 were however, higher than what was obtained from this study (see Table 3).

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

TheBCF 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 was > 1 in site 1 (see Table 3). Only *Amaranthus hybridus*(site 1) was suitable as both phytoextractor and stabilizer of As. The rest plants were only suitable forphytostabilization of As. The TFs < 1 indicated preference of these plants in storing and accumulation of As in their roots. Most of these plants were not suitable for phytominig and very likely the edibles/vegetables may not accumulate above permissible level of As.BCFs > 1 indicated that more As was accumulated in plants than in soils as seen among the few plants. 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 (see Table 3). 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 were higher (on average) than the 1.0 to 5.7 BCF recorded in *A. dubius* (Mellem *et al*, 2012). The likelyhood of health hazard from the 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 was the least among studied metals (see Table 3).

3.4 Cadmium (Cd)

The concentrations of Cd recorded in soils from this study were 1.53mg/kg to 16.67mg/kg (see Table 4). According to Rudnick and Gao, 2003, Cd limit in uncontaminated soil is 0.10mg/kg. This limit is in contrast and lower than thevalues obtained from this study (see Table 4). The European commission, Luxembourg Council directive, 1986 limit of Cd in soil is 0.20mg/kg. The obtained range from this study was higher than this value (see Table 4). From other studies such as Papadopoulos *etal*, (2015); Bradford *etal*, (1996); the soil contents of Cd were 1.40mg/kg and 0.36mg/kg respectively. The observed range from this study was 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 in the shoots and leaves (see Table 4).This is in agreement with Jyotsna Kaushal & Pooja Mahajan, 2022, finding that Cd was readily absorbed by roots and transported to other parts. However, this study is in contrast to their observation that Cd distribution among plants parts were regular.Balabanova *etal*, (2015) in their study recorded Cd of 0.05 to 0.09mg/kg and 0.03 to 0.07 respectively in roots and shoots of *Rumexacetosa*. According to Sinka (2018), 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 (see Table 4). The relatively higher than unpolluted soil limit in Cd concentration may not be unconnected with the pollution from the dumps.

Table 4: Concentration of Cd (mg/kg) in Soils and Plant Tissues

Scientific name	Site no.	Soil	Root	Shoot	Leaf	BCF	TF	BAC	TF_l	EF_l	ME (%) Shoot
Amaranthushybridus *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	
	5	11.00	2.00	1.00	2.00	0.18	0.50	0.09	1.00	0.18	
Average values		5.47	2.75	3.50	2.00	0.99	1.38	1.50	0.87	0.45	
Amaranthusviridis 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	
	7	15.33	5.00	4.00	3.00	0.33	0.80	0.26	0.60	0.20	
Average values		10.33	4.33	2.67	2.00	0.59	0.62	0.26	0.80	0.27	
Abelmoschusesculentus *AE	4	3.00	8.00	5.00	2.00	2.67	0.63	1.67	0.25	0.67	42.31
	7	15.33	3.00	6.00	2.00	0.20	2.00	0.39	0.67	0.13	
Average values		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
	5	11.00	12.00	8.00	3.00	1.09	0.67	0.73	0.25	0.27	
Average values		6.92	6.00	4.00	3.50	0.55	0.34	0.36	0.125	0.84	
Colocasiaasculenta*CA	5	11.00	1.00	5.00	0.00	0.09	5.00	0.45	0.00	0.00	40.63
	6	16.67	13.00	8.00	5.00	0.78	0.62	0.48	0.38	0.30	
Average values		13.84	7.00	6.50	2.50	0.44	2.81	0.47	0.29	0.15	
Corchorusaestuans *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	
	1	1.53	1.00	5.00	0.00	0.65	5.00	3.27	0.00	0.00	
Average values		7.01	9.5	5.67	0.67	0.87	2.79	1.53	0.02	0.13	
Laporteaaestuans *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	
	7	15.33	12.00	10.00	3.00	0.98	0.83	0.65	0.25	0.20	
Average values		6.56	7.00	6.67	2.00	2.24	1.28	2.20	0.50	0.62	
Physalisangulata *PA	2	2.83	4.00	1.00	2.00	1.43	0.25	0.35	0.50	0.71	21.74
	6	16.67	9.00	4.00	3.00	0.54	0.44	0.24	0.33	0.18	
Average values		9.73	6.50	2.50	2.50	0.99	0.35	0.30	0.42	0.45	
Sidaacuta *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**

The concentration of Cd varied from 1.0mg/kg-5.0mg/kg in leaves. The range of Cd from thestudy area was higher than the 0.02mg/kg (WHO, 1996); the 1.00mg/kg and 1.10mg/kg by Podlesakove *et al'*s (2002) permissible limits in edibles/vegetables. Eating any of these plants as vegetables/edibles may not be healthy as there are no known mechanisms of ridding the body of Cd. Cadmiumhas been implicated in kidney disorder, bone disease, heart diseases, bronchitis, lung cancer, cancer emphysema etc (Ali, 2018).

3.4.1 The BCF, TF and BAC for Roots, Shoots and Leaves

The BCFvaried from 0.16 in *Amaranthus hybridus* (site 6) to 5.23 in *Laportea aestuans* (site 1). The TF varied from 0.25 in *Physalis angulata* to 6.00 in *Sida acuta* (Table 4). Plants that showed BCF, TF or BAC> 1 are said to have potential for phytoextraction (Baker and Brooks, 1989). Therefore, *Amaranthus hybridus* (site 1 and 4), *Abelmoschus esculentus* (site 4) and *Laportea aestuans* (site 1) were the potential species for phytoextraction of Cd from the soils. The BCF > 1, TF and BAC< 1 had also been used to evaluate phytostabilization of metals by plants (Lorestani *etal*, 2011; Fang *et a*l., 2021). *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 (see Table 4). The BAC ranged from 0.06 to 5.23. This also implied that these plants have potential for translocation and accumulation of Cd above-ground tissues. This indicated that Cd was easily absorbed by roots and transported to the shoots (Suman, 2018; Fang *et a*l., 2021). The roots to leaves TF and soil to leaf accumulation were in most plants less than < 1 except in four plants at various locations. This implied inefficiency in translocation and accumulation abilities of the leaves compared to the shoots. This observation not withstanding, the leaves had reasonable level of Cd. Four plants recorded EF>1, an indication of enrichment of Cd in the leaves.The metal uptake efficacy of Cd ranged from 21.74 to 50.96%. This range was slightly higher than that for Cr. The Co ME% value was the highest (28.99 to 89.08%).

4.0 CONCLUSION

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 could be phytomined from some of the plants.The prospect of mining As from the plants was 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).

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