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Comparative Chelate-assisted Phytoextraction of Heavy Metals by *Jatropha curcas, Jatropha gossypifolia* and *Jatropha multifida* Cultivated on Soil Collected from Selected Dumpsites in Ekiti State, Nigeria

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Author's contribution

This work was carried out solely by the author. The author EEA designed the study, carried out the experiment, performed the statistical analysis, wrote the protocol, and wrote the first draft of the manuscript, managed literature searches and read and approved the final manuscript.

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ABSTRACT

Background: It is needful to design a process that will lead to the use of fast growing tropical plants for phytoextraction studies.
Study Design: It is an analytical study.
Place and Duration of Study: The study was conducted between October 2010 and June 2012 on selected dumpsites located in Ekiti State, Nigeria.
Methodology: Bulk soil samples were collected from selected dumpsites on seven points at interval of 10 m, starting from top of the slope. Physicochemical and heavy metals content of soil were determined on bulk and fractional soil samples, using sequential extraction technique. The heavy metals were analyzed using atomic adsorption spectrophotometer, prior to plants' cultivation. Heavy metal concentration of plant with and without 1g/kg EDTA was determined in different sections of plant by flame atomic absorption spectrophotometer, in other to determine

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their phytoextraction potentials.
Results: The result revealed the mean value of pH (6.02±0.11-6.31±0.12), organic matter content (3.00±0.08-7.00±0.13%) and the CEC (59.20-62.40 mmol/kg) to be highest at Aba Egbira dumpsite. The result of sequential extraction revealed that heavy metal were distributed in fraction soil samples in the order 75>150>350>495>1000 µm, showing the effect of particulate site on the availability of heavy metals. Application of EDTA increased mobility of heavy metals from soil to shoot of plants with concentration of Cd in *J. curcas, J. gossypifolia and J. multifida* in the following range; (372.0-440.1; experiment, 150.2-186.6; control), (377.5-418.2; experiment, 142.2-202.4; control) and (455.0-530.6; experiment, 245.0-259.2; control) while Cu and Pb ranged from (921.0-118.0; experiment, 405.0-821.0; control), (818.0-962.0; experiment, 442.0-650.0; control) and (1079.0-1138.0; experiment, 644.0-686.0; control) and Pb (384.4-426.2; experiment, 242.2-283.0; control), (328.0-376.0; experiment, 159.0-186.2; control) and (417.0-436.0; experiment, 330.0-370.7; control) mg/kg respectively, in all dumpsites investigated. Bioaccumulation factor (BF), translocation factor (TF) and remediation ratio (RR) greater than one showed that they are effective in chelant-assisted phytoextraction.
Conclusion: Therefore, the use the species of *Jatopha* are advocated for phytoextraction Cd, Pb and Cu.

Keywords: Chelator; phytoextration; heavy metals; Jatropha species.

1. INTRODUCTION

The indiscriminate dumping of waste, most especially metallic and hazardous waste have become common practice in Nigeria, where most waste dumpsites are located close to residential area, markets and road side [1]. Accumulation of toxic heavy metals such as Cd, Zn Cu, Pb, Cr, As and their potential effects on human health, agriculture and ecosystem has since generated concern by environmentalist [2,3]. It is generally believed that these heavy metals are sometimes hazardous to health. Such health risks and hazards have been widely reported [4,5]. However, the clean-up of heavy metals from polluted soil is emergent and imperative. Leon et al. [6] reported that some plant species are endemic to metalliferous soils and can tolerate greater than usual amounts of heavy metals or other toxic compounds. Such plants have been employed in phytoextraction studies; and those that can accumulate high levels of heavy metals in their harvestable portion without symptoms of phtotoxicity [1,4,7]. Hyper accumulators are plants capable of accumulating extraordinarily high metal levels; such plant has genetic potential to clean-up heavy metals contaminated soils [8]. Ultimately, the plant's potential for phytoextraction depends on several factors, including the extent of soil contamination, metal availability for uptake into roots (bioavailabilty) and plant ability to intercept absorbs and accumulates metals in shoot [7]. Alvarez et al. [9] reported the potential use of fast growing pioneer plant species for phytoremediation strategies. Though, some of these are limited in scope due to low biomass production; as a candidate plant for phytoextraction must produce large biomass and resists phytotoxicity [1,10]. However, the phytoextraction efficiencies of these fast growing plants have been enhanced with chelating agents such as ethylene diamine tetracetic acid (EDTA), ethylene glycol tetra acetic acid (EGTA), citric acid; just to mention a few [1,11,12]. *Jatropha curcas, Jatropha* gossypifolia and *Jatropha multifida* are fast growing tropical plants, which are found to grow naturally on dumpsites. Therefore, the objective of the research was to investigate the role of EDTA on comparative phytoextraction of heavy metals by *J. curcas, J. gossypifolia* and *J. multifida*, with a view to applying them in cleaning up heavy metals contamination from the environment.

2. MATERIALS AND METHODS

2.1 Collection, Preparation and Analysis of Soil Samples

Bulk soil samples were collected from four different dumpsites located at Aba Egbira (7.41° 288^{1}N; 5.15° 661^{1}E), Atikankan (7.37° 032^{1}N, 5.13° 263^{1}E) at Ado Ekiti (Fig. 1) and Igbehin Street (7.29° 729^{1}N; 5.13° 263^{1}E), and Moshood road (7.39° 363^{1}N; 5.13° 931^{1}E) at Ikere Ekiti (Fig. 2). The samples were collected at the depth of 0-15 cm from seven points at interval of 10 m down the slope, using calibrated soil auger. Control samples were taken 200 m away from the last sampling point on each dumpsite.

Soil samples were separately oven dried at 40℃ grounded with a wooden roller and was allowed to pass through 4 mm mesh. Each sample was immediately placed in a previously leached polythene bags and tightly sealed.

In the pH determination, 2 g of each sample was weighed into a 50 ml beaker and 20 ml distilled/deionized water was added. The beaker was allowed to stand for 30 minutes with occasional stirring. The pH meter that had been standardized with potassium hydrogen phthalate and ammonium buffer was inserted into each solution and pH determined.

Organic matter content of soil samples were determined by loss on ignition according to AOAC [13].

Cation Exchange Capacity (CEC) was determined by a method described by Jackson [14] by measuring 1 mol/L acetic acid solution, which pH was determined. The 2.5 g of soil was placed in a 20 ml beaker with 25 ml acetic acid; the solution was stirred for a period of one hour using a mechanical shaker. After agitation the mixture was left undisturbed for complete sedimentation of the soil particles. The pH of the supernatant was read, which the same as that of the mixture was practically. CEC was calculated by, CEC= $mmol_c$ /kg of exchangeable metal cations M equals 0.1kg of dry soil.

2.2 Sequential Extraction of Heavy Metals

The stepwise extraction of heavy metals in different phase of soil was carried out by a method prescribed by Tessier et al. [15] modified by Campanella et al. [16]. The soil had already been sieved by atomic testing sieve shaker to following sizes; >1000, >495, >350. >150 and >75 µm. The metal in aqueous phase of soil was extracted with 45 ml of 1M ammonium acetate at pH 5 with acetic acid under stirring for 24 hours. The exchangeable fraction was determined through extraction with 22.5 ml of hydroxyl ammonium chloride (1M) and 22.5 ml acetic acid (25%), with stirring at room temperature. Metal adsorbed on inorganic soil constituent was extracted with 12.5 ml of 0.1M HCl and stirring for 24 hours. Those associated with organic matter was treated with 12.5 ml of 0.5 M NaOH and stirring for 24 hours, later dried under IR lamp at 60℃ and then digested with 4 ml of 65% HNO_3 and 2 ml of 40% HF in a microwave oven. The metals precipitated as pure or mixed solids were extracted using 12.5 ml of 8M HNO_3 and digested for 3 hours at 80℃. Lastly, the residual solid was digested with 4 ml of oxidizing mixture (HNO_3: HCl) and 6 ml HF in Teflon recipient put in microwave oven. The sample was also shaken with 5.6g HBO_3 to avoid silica evaporation and diluted to 100 ml by deionized water. Concentration of heavy metals was determined using flame atomic absorption spectrophotometer (Perkin Elmer, model 306). The flame atomic absorption spectrophotometer was calibrated by preparing different concentrations of each metal by dilution from the stock (standard) solution for each cation. These were used in preparing linear curves, passing through the origin, for each metal. The wavelength (nm), lamp current (mA) and band width (nm) were adjusted for each metals as follows; Pb (217.0, 5.0, 0.4), Zn (213.9, 5.0, 0.4), Cd (228.8, 5.0, 0.4), Cr (357.9, 5.0, 0.4) and Cu (324.7, 5.0, 0.4) respectively. The flame is oxidizing blue air/ acetylene. These experimental procedures were repeated in all cases, where heavy metals concentrations were determined with flame atomic absorption spectrophotometer.

2.3 Plant Cultivation

Plastic pots each 15 cm high and 20 cm wide were filled with 5 kg soil samples from dumpsites and control sites. The Uniform seedlings of *Jatropha curcas, Jatropha gossypifolia* and *Jatropha multifida* obtained from Plant Science Department Herbarium of Ekiti State University, Ado Ekiti were planted on each pot marked 'experiment' (with application of 1.0 g/kg EDTA) and control (without EDTA application). EDTA application was carried out at preflowering, flowering and mature stages according to Sun et al. [7]. These plastic pots were place in green house, where the plants were watered throughout lifespan and no fertilizer was added. A Petri dish was placed under each pot to collect potential leachates, which were immediately added to each pot to prevent loss of target heavy metals.

2.4 Analysis of Plants

Matured plants were harvested, treated with 0.01 M HCl to remove external heavy metals; they were later separated into root, stem, leaf and fruit. The plants were air-dried and subsequently dried at 700℃ in an oven to complete dryness [17]. They were digested with a solution of 3:1 HNO_3:$HClO_4$ (v/v). Heavy metals concentration was determined using atomic absorption spectrophotometer.

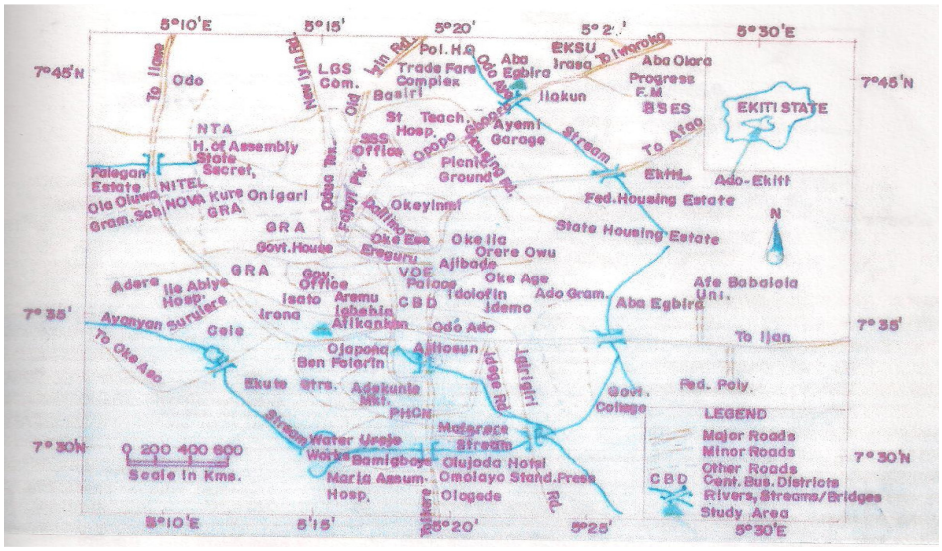

Fig. 1. The study area within Ado - Ekiti township showing sampling locations: Aba Egbira and Atikankan

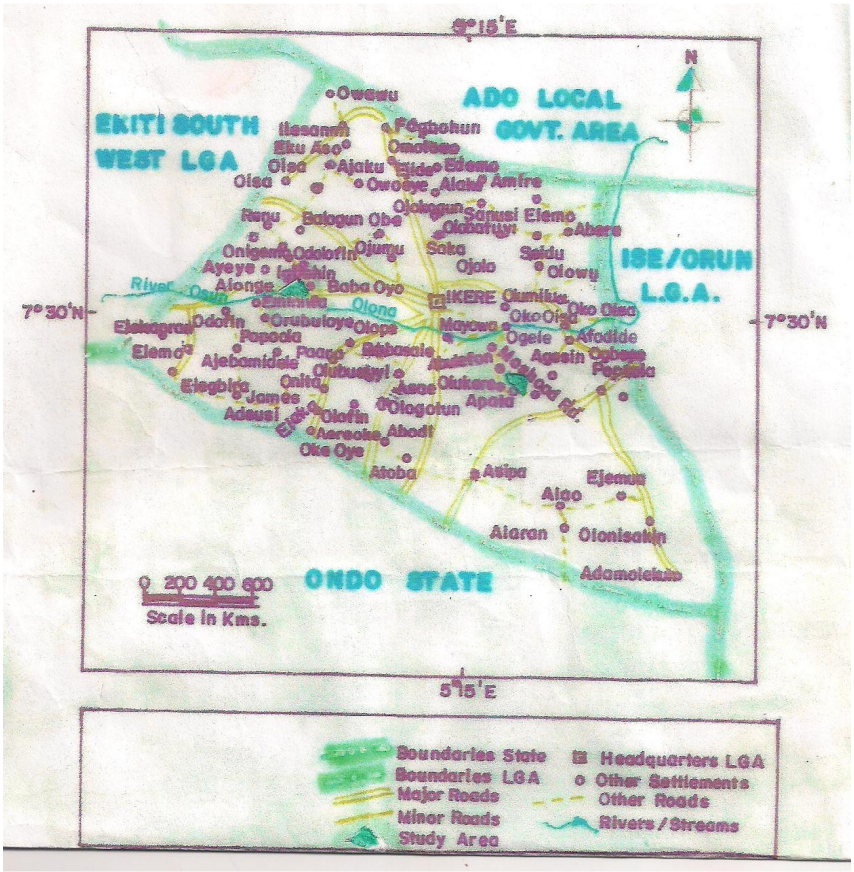

Fig. 2. The study area within Ikere- Ekiti township showing sampling locations: Moshood road and Igbehin street dumpsites

2.5 Data Analysis

All data collected were replicates of three determinations and were analyzed statistically by calculating the mean and significant difference between multiple treatments by LSD test. Translocation factor (TF), the quotient of heavy metals concentration in plant to soil; bioaccumulation factor (BF), the ratio of contaminant in plant to soil; and remediation ratio (RR) were calculated. The remediation ratio was calculated according to this equation:

$$RR\ (\%) = \frac{M_{shoot} \times W_{shoot}}{M_{soil} \times W_{soil}} X\ 100(\%),$$

where Mshoot is concentration of metals in the shoots of plants (mg/kg), Wshoot is the plant dry plant shoot (g); Msoil is concentration metals in soil measured in each pot (mg/kg) Wsoil is the mass of soil in the pot (g). The RR reflects the amount of metals extracted by a plant from soil, which indicate phytoextraction efficiency under chelant-induced experiments.

3. RESULTS AND DISCUSSION

3.1 Physicohemical Characteristics of Soil Samples Collected from Dumpsites and Control Sites

The results of physicochemical characteristics of soil collected from selected dumpsites and control sites are depicted in (Table 1). Soil pH was observed to be comparatively lower in control sites than all dumpsites under investigation. The pH values were obtained to range between 6.02±0.11 and 6.31±0.12, where the highest was pH obtained at Aba Egbira dumpsite. It has been reported that lower pH value will favour availability, mobility and redistribution of heavy metals in various soil fractions [1].

The organic matter content of these dumpsites ranged from 3.00±0.08 to 7.00±0.13, with Aba Egbira having the highest. These values were higher compare to what was obtained on control sites (1.50±0.03 to 5.80±0.08), which could be as a result of dumping of organic wastes on these dumpsites. Moderate levels of organic matter content have been reported to indicate high mineral content [4].

Apart from high mineral content indicated by high organic matter content of dumpsites compared to control sites, higher cation exchange capacity (CEC) values of dumpsites compared to control sites (Table 1) are characteristic of soil ionic elements contents, concentration of clay and mud, texture, degree of compression, levels of porosity and permeability [18]. Moderate values of CEC obtained indicated the redistribution potentials of ionic element in the soil horizon, though the ionic element may be depleted during rainfall; this was prevented by cultivating plants in green house [18].

3.2 Sequential Extraction of Heavy Metals from Dumpsites

(Tables 2 to 5) present the sequential extraction of heavy metals from bulk and fractional samples of soil from Aba Egbira, Atikankan, Igbehin Street and Moshood road dumpsites respectively. Information obtained from all dumpsites showed that particulate size of soil samples has significant effect on the concentration of total metals. The heavy metals concentration in the size fractional samples were found to vary in the order 75>150>350>495>1000 µm, showing that the size 75 µm has the highest concentration of heavy metals in all extractive steps. This same observation was reported by Pagnanelli et al. [19], while trying to explore the same principle on river sediments of abandoned pyrite mining area of Bocchegiano. The classification adopted here (75 to 1000 µm) was based on Dia-zorita and Grosso [20] conventional classification; >2000 µm; gravel, 50-200 µm; sand, 20-50; silt and, 2 µm; clay. This kind of classification was based on texture only not accounting for the mineralogical composition of different particle sizes of samples.

Sequential extraction revealed that antropogenic and mineralogical composition of heavy metals in all extractive phases of soil from all dumpsite investigated (Tables 2, 3, 4, 5 and 6). The model prescribed by Tessier et al. [15] and modified by Campanella et al. [16] was employed. The results revealed that all heavy metals investigated were distributed in all extractive phases, with over 50% of Cd and Pb found in anthropogenic phases of soil, in all dumpsites investigated. (Table 6) provided information on the distribution patterns of heavy metals in each extractive phase, thereby helping in the source identification of heavy metals from the selected dumpsites (lithogenic or anthropogenic). These metals were classified depending on their degree of association with each extractive phase; information regarding bioavailability of these metals is needful in planning phytoextraction

strategies. However, Cd and Pb were observed to be distributed more in anthropogenic phase with values ranging from 58.74-64.71% and 43.82-63.78% respectively in all dumpsites investigated while Cr, Cu Zn were distributed at lesser values; 12.26-20.74%, 31.05-48.42% and 33.97-41.10% respectively.

The reproducibility of the sequential extraction procedures were carried out by comparing the total amount of metals extracted by different reagents during the sequential extraction procedure with the results of the total digestion according to Yuan et al. [21]. The recovery of sequential extraction was calculated as follows:

$$\%\text{Recovery}^{a} = \frac{[\text{Cfraction A+ Cfraction B + Cfraction C + Cfraction D + CfractionE)}]}{[\text{Total digestion}]} \times 100$$

$$\%\text{Recovery}^{b} = \frac{\text{Residual fraction}}{\text{Total digestion}} \times 100.$$

Table 1. Mean physicochemical characteristic of soil samples collected from selected dumpsites

Parameters	Aba Egbira	Atikankan	Igbehin	Moshood
p^H (Dumpsite)	6.31±0.12	6.22±0.16	6.18±0.11	6.02±0.08
(Control)	5.80±0.15	5.60±0.11	5.42±0.11	5.30±0.08
OMC(Dumpsite)(%)	7.00±0.13	5.50±0.18	5.00±0.23	3.00±0.25
Control(%)	5.80±0.09	4.20±0.06	3.80±0.04	1.50±0.03
CEC(Dumpsite)(mmol/kg)	62.40±0.07	60.38±0.18	59.80±0.18	59.20±0.09
(Control)(mmol/kg)	59.42±0.06	59.82±0.20	56.82±0.12	56.32±0.10

OMC: Organic Matter Content CEC: Cation Exchange Capacity

Table 2. Sequential extraction of bulk and size fractional samples of soil from Aba Egbira dumpsite (mg/Kg)

	StepI	StepII	StepIII	StepIV	StepV	Residue
Cd						
Bulk	502.00	336.00	10.92	4.60	80.00	446.00
>1000	68.21	40.92	6.45	0.71	10.00	70.82
>495	75.22	45.91	7.02	0.73	12.42	71.51
>350	78.90	59.22	8.54	0.84	14.92	88.72
>150	81.70	91.22	9.14	0.92	14.92	88.21
>75	134.00	102.00	10.91	1.31	18.07	142.86
Total	438.03	339.27	42.06	4.51	70.21	445.12
Mean	87.60	67.85	8.41	0.90	14.04	91.02
Cr						
Bulk	2.65	2.62	2.05	0.12	2.92	272.00
>1000	1.13	1.02	1.07	0.10	1.48	32.11
>495	2.05	1.04	1.09	0.10	1.52	44.20
>350	2.72	1.06	1.07	0.10	1.72	46.14
>150	2.84	1.06	2.01	0.10	1.84	50.12
>75	3.08	3.18	1.98	0.13	2.84	74.40
Total	11.82	7.36	7.22	0.53	9.40	246.97
Mean	2.36	1.47	1.44	0.11	1.88	49.39
Cu						
Bulk	15.04	20.82	22.50	22.35	95.00	170.00
>1000	2.42	3.62	4.85	1.04	14.20	16.21
>495	3.59	4.20	4.94	1.51	14.61	22.42
>350	4.00	4.32	5.01	1.52	16.64	38.32
>150	4.22	4.72	5.84	1.55	23.21	42.58

Table 2 continued……

>75	4.82	5.22	6.62	22.7	24.50	60.44
Total	19.05	22.08	27.26	7.89	93.16	179.97
Mean	3.81	4.42	5.45	1.58	18.63	35.99
Pb						
Bulk	1152.00	503.00	108.00	1.42	810.00	3182.00
>1000	168.28	35.53	73.73	0.56	118.44	322.00
>495	182.44	71.25	140.82	1.22	134.62	406.00
>350	195.23	81.00	172.40	1.46	143.20	541.00
>150	215.14	94.24	204.10	1.94	182.40	604.00
>75	228.00	191.17	321.40	3.47	192.20	720.00
Total	989.09	473.19	912.45	8.65	770.86	2593.0
Mean	197.82	94.64	182.49	1.73	154.17	518.60
Zn						
Bulk	78.30	101.04	84.20	58.50	58.10	82.00
>1000	3.30	7.62	5.90	1.34	4.49	46.00
>495	3.40	8.22	6.41	1.42	5.42	48.22
>350	3.44	14.46	6.52	1.44	6.58	49.20
>150	3.96	25.82	6.64	1.45	6.72	57.42
>75	13.78	36.40	7.18	2.00	7.42	59.52
Total	27.88	92.52	32.65	7.65	30.63	260.78
Mean	5.58	18.50	6.53	1.53	6.13	52.16

Legend: StepI: Aqueous Phase StepII: Exchangeable Phase StepIII: Adsorbed on Inorganics IVAssociated with Organics Stepv: Precipitated as Pure or Mixed

It was also observed that there was a good agreement between the concentration of metals from the total digestion and sums of six fractions (Table 6), showing reliability and reproducibility of results. The recovery[a] is the percentage of heavy metals present as result of human activities while Recovery[b] is the percentage of heavy metal in the mineralogical matrix of soil.

3.3 The Effect of EDTA on Plant Biomass

The heights of three species of *Jatropha* cultivated on soil of dumpsites with and without application of EDTA are shown in (Fig. 3). On the application of EDTA, the heights of the three species of plants were in the sequence of mature stage > flowering stage >pre-flowering stage. *J. curcas* grew with highest biomass compared to *J. gossypifolia* and *J. multifida.* The sequence of biomass production on dumpsites and control sites were in the sequence *J. curcas > J. multifida > J. gossypifolia.* However, in all cases, the plants cultivated on Aba Egbira dumpsite grew with more biomass compared with other dumpsites; this could be as a result of high organic matter content, indicating high fertility of the dumpsites. Mant et al. [22] reported that a candidate plant for phytoextraction must grow healthily without symptoms of phytotoxicity; these symptoms only appear at pre-lowering stage of these plants in all dumpsites. Zhou and Song [23] also reported that an ideal hyperaccumulators should be high yielding and must accumulate target metals.

3.4 Comparative EDTA Accumulation of Metals by Plants

(Tables 7, 8 and 9) present the concentrations in the tissues of three species of *Jatropha*. The results showed that the concentration of heavy metals were highest with the application of EDTA when compared with control. Concentration of Cd in the shoot of plants were observed in *J. curcas, J. gossypifolia* and *J. multifida* in the following range; (372.0-440.1; experiment, 150.2-186.6; control) (377.5-418.2; experiment, 142.2-202.4; control) and (455.0-530.6; experiment, 245.0-259.2) mg/kg respectively, in all dumpsites investigated. Hyperaccumulators are species capable of accumulating metals at levels 100-fold greater than those typically measured in the shoot of non-accumulators plants. Thus, a hyperaccumulator of Cd will concentrate more than 100mg/kg Cd [4]. From the results presented, the three species of *Jatropha* could be potentially good candidate for phytoextraction of Cd from contaminated sites.

Table 3. Sequential extraction of bulk and size fractional samples of soil from Atikankan dumpsite (mg/kg)

	StepI	StepII	StepIII	StepIV	StepV	Residue
Cd						
Bulk	390.00	236.00	29.96	5.42	78.00	450.00
>1000	57.21	29.00	5.45	0.71	10.00	70.20
>495	64.20	30.22	6.00	0.83	11.40	71.50
>350	7.80	42.60	6.44	0.90	13.81	80.40
>150	70.60	46.00	7.00	0.99	17.20	88.00
>75	123.00	81.00	10.90	1.40	18.00	132.20
Total	382.81	228.82	228.82	35.79	4.83	70.41
Mean	76.56	45.76	7.16	0.97	14.08	88.46
Cr						
Bulk	2.55	2.52	1.95	10.2	13.00	292.22
>1000	1.03	0.97	0.92	0.04	1.18	28.10
>495	1.90	0.98	1.02	0.05	1.24	32.42
>350	1.74	0.98	1.17	0.06	1.62	35.14
>150	1.84	1.06	1.22	0.08	1.74	52.46
>75	3.08	2.08	2.98	0.12	6.74	105.22
Total	9.59	6.07	7.31	0.35	12.52	253.34
Mean	1.92	1.21	1.46	0.07	2.50	50.67
Cu						
Bulk	14.04	18.62	21.25	20.35	92.00	160.00
>1000	1.42	2.65	3.55	1.22	6.12	13.12
>495	3.32	3.46	4.43	1.35	7.61	28.14
>350	3.82	3.58	4.46	1.48	7.68	42.12
>150	4.00	3.64	5.74	1.72	8.28	53.33
>75	4.68	4.08	6.42	2.81	10.30	77.18
Total	17.24	17.41	24.60	8.58	39.99	213.89
Mean	3.45	3.48	4.92	1.72	8.00	42.78
Pb						
Bulk	106.00	708.00	102.00	8.62	67.00	1440.00
>1000	15.20	45.50	8.10	0.57	7.08	21.00
>495	17.80	81.20	13.00	0.71	8.06	108.00
>350	18.60	92.00	16.00	1.59	8.08	142.00
>150	19.20	102.00	16.20	1.89	19.06	504.00
>75	28.00	304.20	39.40	3.00	22.12	524.00
Total	98.80	624.90	92.70	7.76	64.40	1299.00
Mean	19.76	124.98	18.54	1.55	12.88	259.80
Zn						
Bulk	68.40	96.24	72.05	2.84	56.10	128.40
>1000	1.68	7.06	4.02	0.01	4.29	24.00
>495	1.82	8.14	5.61	0.14	6.38	36.00
>350	2.45	14.25	5.72	0.19	6.52	40.00
>150	10.78	20.40	6.04	0.20	7.22	60.00
>75	10.82	32.82	7.04	1.21	7.46	90.00
Total	27.55	82.67	28.43	1.75	31.87	250.00
Mean	5.51	16.53	5.69	0.35	6.37	50.00

Legend: StepI: Aqueous Phase StepII: Exchangeable Phase StepIII: Adsorbed on Inorganics IVAssociated with Organics Stepv: Precipitated as Pure or Mixed

Table 4. Sequential extraction of bulk and size fractional samples of soil from Igbehin Street dumpsite (mg/kg)

	StepI	StepII	StepIII	StepIV	StepV	Residue
Cd						
Bulk	125.00	70.00	75.00	0.72	19.00	168.00
>1000	18.20	8.50	10.00	0.03	2.40	22.00
>495	19.00	9.22	11.22	0.04	3.20	24.00
>350	22.20	10.00	12.00	0.07	3.90	34.00
>150	30.20	10.34	13.00	0.10	4.68	36.00
>75	38.30	28.33	26.21	0.43	4.72	42.00
Total	127.90	66.39	72.43	0.67	18.90	158.00
Mean	25.58	13.28	14.49	0.13	3.78	31.60
Cr						
Bulk	3.05	2.64	2.75	1.13	5.76	172.11
>1000	1.03	1.02	1.00	0.07	1.42	12.10
>495	1.05	1.02	1.12	0.08	1.86	15.24
>350	1.72	1.04	1.48	0.09	1.30	20.56
>150	1.84	1.07	1.49	0.10	1.32	36.00
>75	4.98	3.15	3.02	2.02	4.60	10.24
Total	10.62	7.3	8.11	2.36	10.50	94.14
Mean	2.12	1.46	1.62	0.47	2.10	18.83
Cu						
Bulk	11.40	5.82	19.80	18.35	96.40	301.77
>1000	1.20	1.26	2.82	1.07	7.12	20.06
>495	2.15	1.33	4.70	1.12	7.21	33.05
>350	2.67	1.34	4.92	1.28	8.46	38.06
>150	2.92	1.48	5.60	1.50	9.06	50.17
>75	3.15	4.22	5.28	1.84	10.14	65.82
Total	11.91	9.63	23.32	6.81	41.99	207.16
Mean	2.38	1.93	4.66	1.36	8.40	41.43
Pb						
Bulk	96.00	482.20	281.30	9.43	81.00	1025.00
>1000	10.42	35.62	38.33	0.57	11.85	152.00
>495	10.84	71.36	40.72	1.23	13.45	164.00
>350	19.62	81.20	56.00	1.47	14.33	168.00
>150	21.60	94.30	64.00	1.97	18.22	169.00
>75	22.80	191.20	76.00	1.97	19.33	252.00
Total	85.28	473.68	275.05	7.21	77.18	905.00
Mean	17.06	94.74	55.01	1.44	15.44	181.00
Zn						
Bulk	66.43	96.80	96.00	48.24	62.00	134.00
>1000	2.42	7.14	6.90	0.76	6.02	28.00
>495	3.28	7.14	7.41	0.82	6.04	29.00
>350	3.62	18.17	7.52	0.94	7.12	31.00
>150	3.84	18.17	7.64	1.01	7.22	60.42
>75	11.28	8.12	28.18	10.20	17.40	82.00
Total	24.44	58.74	57.65	13.73	43.80	230.42
Mean	4.89	11.75	11.53	2.75	8.76	46.08

Legend: StepI: Aqueous Phase StepII: Exchangeable Phase StepIII: Adsorbed on Inorganics IVAssociated with Organics Stepv: Precipitated as Pure or Mixed

Table 5. Sequential extraction of bulk and size fractional samples of soil from Moshood road dumpsite (mg/kg)

	StepI	StepII	StepIII	StepIV	StepV	Residue
Cd						
Bulk	48.00	45.00	29.00	5.24	7.50	52.00
>1000	6.81	4.00	2.00	0.24	1.00	7.00
>495	7.52	5.51	2.10	0.82	1.24	7.12
>350	7.82	5.90	3.00	0.93	1.48	8.20
>150	8.12	9.12	4.02	0.94	1.49	8.20
>75	13.40	17.20	12.10	2.28	1.80	14.20
Total	43.67	41.73	23.22	5.21	7.01	44.65
Mean	8.73	8.35	4.64	1.04	1.40	8.93
Cr						
Bulk	0.05	0.06	0.08	0.12	0.07	2.60
>1000	0.01	0.01	0.01	0.01	0.01	0.22
>495	0.01	0.01	0.01	0.01	0.01	0.24
>350	0.87	0.65	0.62	0.87	1.04	2.28
>150	0.01	0.01	0.02	0.01	0.01	0.29
>75	0.04	0.05	0.04	0.16	0.05	1.10
Total	0.94	0.73	0.70	1.06	1.12	4.13
Mean	0.18	0.15	0.14	0.21	0.22	0.83
Cu						
Bulk	10.40	4.62	26.67	13.20	116.00	170.00
>1000	0.90	1.16	4.87	1.12	11.20	23.42
>495	1.10	1.23	5.62	1.33	11.40	21.46
>350	1.24	1.36	5.87	1.87	11.60	36.24
>150	1.28	1.46	6.82	2.02	11.62	40.47
>75	2.08	4.07	6.90	4.48	52.13	43.33
Total	6.60	9.28	30.08	10.82	97.95	164.92
Mean	1.32	1.86	6.02	2.16	19.59	32.98
Pb						
Bulk	76.18	233.00	65.00	5.46	88.00	237.0
>1000	13.82	14.00	7.37	0.52	11.83	36.00
>495	13.93	14.30	8.08	0.62	12.46	47.00
>350	14.20	15.66	9.03	0.78	14.30	47.00
>150	15.60	90.60	11.14	0.87	15.22	47.00
>75	19.28	96.00	28.43	2.07	19.30	55.00
Total	76.83	230.56	64.05	4.86	73.11	232.00
Mean	15.37	46.11	12.81	0.97	14.62	46.40
Zn						
Bulk	56.42	80.22	76.02	46.40	32.00	112.20
>1000	1.62	6.02	1.12	0.64	8.73	49.24
>495	1.82	6.05	1.12	0.64	8.73	49.24
>350	1.84	6.71	1.15	0.66	9.06	50.06
>150	1.85	6.82	1.93	0.77	9.42	56.41
>75	10.72	6.93	6.03	18.80	18.40	61.00
Total	17.85	32.53	11.35	21.51	54.34	265.95
Mean	3.57	6.51	2.27	4.30	10.87	53.19

Legend: StepI: Aqueous Phase StepII: Exchangeable Phase StepIII: Adsorbed on Inorganics IVAssociated with Organics Stepv: Precipitated as Pure or Mixed

Table 6. Recovery of sequential extraction and total digestion of soil sample from dumpsites

Element	Total digestion (mg/kg)	Sum[a] (mg/kg)	Recovery[a] (%)	Sum[b] (mg/kg)	Recovery[a] (%)
Aba Egbira					
Cd	1379.00	809.96	58.74	445.00	32.26
Cr	282.36	36.33	12.86	246.97	87.46
Cu	345.75	167.43	48.42	179.97	52.05
Pb	5756.00	3154.24	54.80	2593.00	45.00
Zn	465.50	191.33	41.10	260.78	56.02
Atikankan					
Cd	1188.58	716.22	60.22	44.23	37.21
Cr	292.22	35.84	12.26	253.34	86.69
Cu	326.26	107.82	33.05	213.89	65.56
Pb	2431.62	887.66	53.42	1299.00	36.50
Zn	424.03	172.53	40.68	250.0	58.96
Igbehin					
Cd	459.72	281.09	61.14	158.00	34.37
Cr	187.44	38.89	20.74	134.14	71.56
Cu	301.77	93.71	31.05	207.12	68.64
Pb	1974.93	862.03	45.82	901.00	43.65
Zn	407.47	174.35	42.78	237.42	58.27
Moshood					
Cd	186.74	120.84	64.71	44.65	23.91
Cr	2.60	0.41	15.76	2.13	81.92
Cu	331.02	154.73	46.74	174.42	52.69
Pb	704.64	449.41	63.78	237.00	33.63
Zn	403.44	137.05	33.97	264.82	65.64

J. curcas, J. gossypifolia and *J. multifida* were observed to accumulate Cu in their shoot ranging from; (921.0-118.0; experiment, 405.0-821.0; control), (818.0-962.0; experiment, 442.0-650.0; control) and (1079.0-1138.0; experiment, 644.0-686.0; control) while Pb were accumulated in the following range; (384.4-426.2; experiment, 242.2-283.0; contro), (328.0-376.0; experiment,159.0-186.2; control) and (417.0-436.0;experiment, 330.0-370.7;conrol) respectively in all dumpsites investigated. The results presented were lesser than the threshold value reported by Baker et al. [4], for Cu and Pb except at Abaegbira and Atikankan dumpsites, where *J. curcas* accumulated Cu in its shoot at levels greater than 1000 mg/kg. Also *J. multifida* accumulated Cu in its shoot at levels greater than 1000 mg/kg in all dumpsites investigated.

However, there is possibility of proposing the three species of *Jatropha* considered in this report for phytoextraction; a candidate for plant for phytoextraction must accumulate high concentrations of target metals in their above ground masses [24].

Conversely, comparatively lower concentrations of Cr and Zn were observed in all *Jatropha* species in all dumpsites investigated (Tables 7, 8, 9), these values fell below the threshold values reported by Baker et al. [4]. However, heavy metals accumulation in the harvestable tissues of plant does not only confer hyperaccumulation tendencies on plant, phytoextraction efficiency should also be considered [1,7,25].

3.5 Phytoextraction Efficiency

The phytoextraction efficiency of a supposed hyperaccumulators is evaluated by bioaccumulation factor (BF), translocation factor (TF) and remediation ratio (RR) [7]. According to the results presented in (Tables 10, 11 and 12), BF, TF and RR values were greater than one on the application of EDTA for Cd, Cu and Pb indicating the hyperaccumulative tendencies of the three species of *Jatropha* by the target heavy metals. These values were lesser than the ones observed in control.

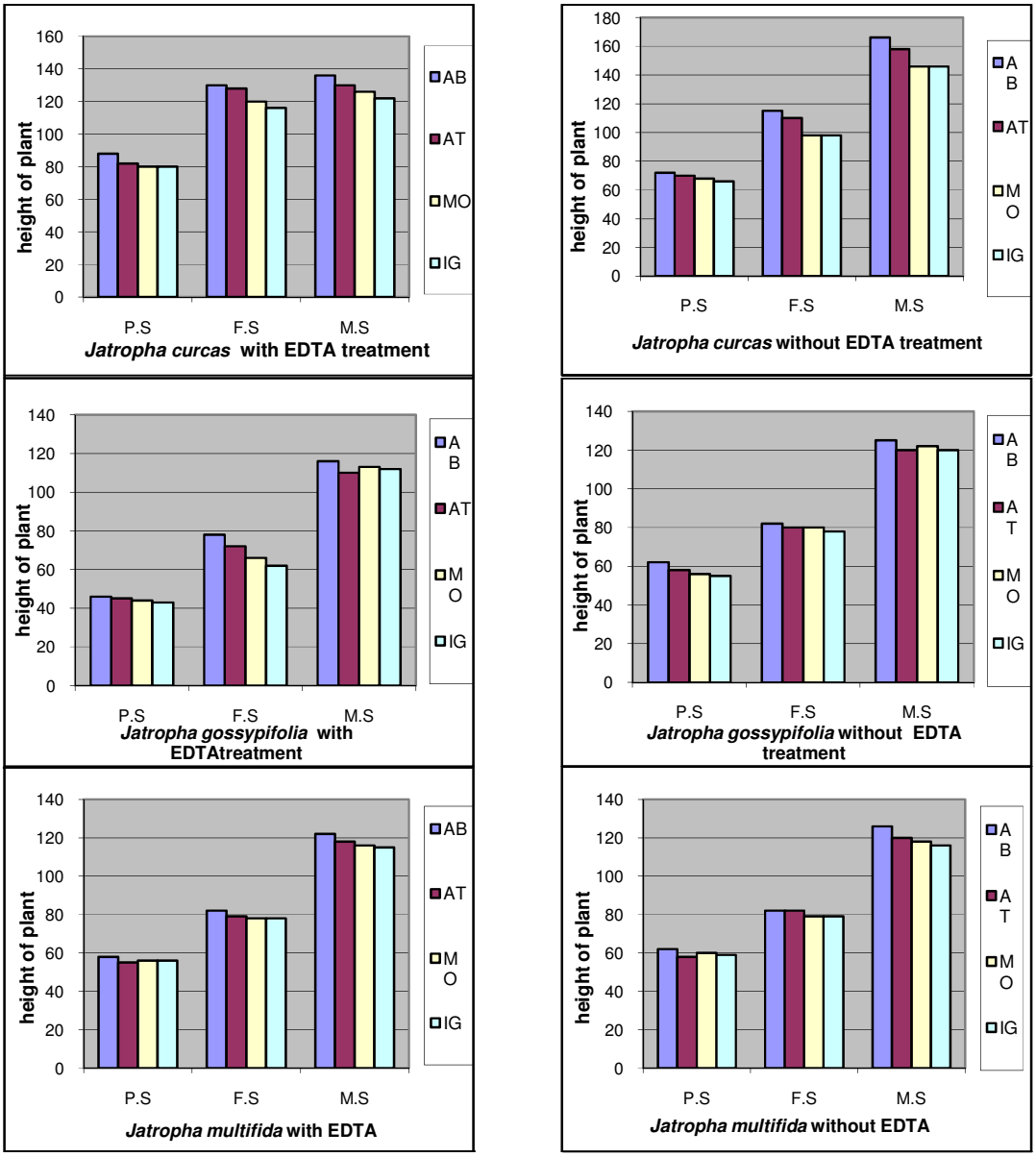

Fig. 3. Heights of *Jatropha curcas, Jatropha gossypifolia* and *Jatropha multifida* at different stages of germination with and without EDTA treatmen

Table 7. Concentration of heavy metals in the tissues of *Jatropha curcas* with and without EDTA treatment (mg/kg) on selected dumpsites

	Root		Steam		Leaf		Fruit		Shoot	
Cd	**Exp**	**Cont**	**Exp**	**Cont**	**Exp**	**Cont**	**Exp**	**Cont**	**Exp**	**cont**
AB	86.3_{a}	52.0_{a}	58.1_{a}	20.6_{a}	286.0_{a}	120.0_{a}	96.0_{a}	46.0_{a}	440.1	186.6
AT	80.0_{a}	32.0_{a}	56.0_{ab}	22.0_{b}	280.0_{ab}	102.0_{ab}	95.0_{a}	42.0_{a}	431.0	166.0
IG	78.6_{b}	30.0_{a}	50.0_{b}	19.6_{c}	268.0_{b}	122.0_{a}	72.0_{b}	38.2_{b}	390.0	179.8
MO	76.0_{b}	23.0_{b}	50.0_{b}	17.2_{d}	252.0_{c}	100.0_{b}	70.0_{b}	33.0_{bc}	372.0	150.2
Cr										
AB	19.8_{a}	7.6_{a}	23.2_{a}	13.8_{a}	28.0_{a}	16.0_{a}	19.8_{a}	12.6_{a}	70.8	42.4
AT	18.6_{b}	6.8_{ab}	23.0_{b}	13.3_{a}	27.3_{a}	16.8_{a}	19.6_{a}	12.0_{a}	69.9	42.1
IG	17.8_{c}	6.8_{ab}	21.0_{ab}	12.8_{ab}	26.4_{ab}	15.2_{ab}	16.0_{ab}	11.6_{b}	63.4	39.6
MO	17.6_{d}	6.2_{b}	21.6_{ab}	12.0_{b}	26.0_{ab}	15.2_{ab}	17.6_{ab}	11.8_{b}	65.2	39.0
Cu										
AB	286.0_{a}	122.0_{a}	432.0_{a}	341.0_{a}	486.0_{a}	382.0_{a}	196.0_{a}	98.0_{a}	1114.0	821.0
AT	272.0_{b}	126.0_{ab}	440.0_{a}	240.0_{a}	482.0_{a}	386.0_{a}	196.0_{a}	96.0_{a}	1118.0	722.0
IG	282.0_{a}	113.0_{c}	382.0_{b}	154.0_{b}	386.0_{b}	202.0_{b}	198.0_{a}	70.0_{b}	966.0	426.0
MO	276.0_{b}	113.0_{c}	351.0_{c}	106.0_{c}	384.0_{b}	203.0_{b}	186.0_{ab}	96.0_{a}	921.0	405.0
Pb										
AB	86.0_{a}	56.0_{a}	104.2_{a}	84.6_{a}	196.0_{a}	112.4_{a}	126.0_{a}	86.0_{a}	426.2	283.0
AT	84.0_{a}	52.2_{ab}	103.3_{ab}	80.2_{ab}	186.0_{b}	111.0_{b}	136.0_{b}	80.0_{ab}	425.3	271.2
IG	82.6_{ab}	50.6_{ab}	104.6_{ab}	76.3_{ab}	170.0_{c}	91.2_{c}	112.0_{c}	81.0_{ab}	386.6	248.5
MO	80.9_{ab}	46.2_{b}	102.4_{b}	70.2_{b}	168.0_{d}	96.0_{d}	114.0_{d}	76.2_{b}	384.4	242.2
Zn										
AB	6.8_{a}	3.6_{a}	8.2_{a}	4.5_{a}	12.6_{a}	5.2_{a}	3.6_{a}	1.8_{a}	24.4	11.5
AT	5.6_{b}	3.5_{a}	8.6_{a}	4.0_{ab}	11.8_{ab}	5.2_{a}	3.3_{a}	1.8_{a}	23.7	11.0
IG	4.2_{c}	2.8_{b}	8.6_{a}	3.8_{ab}	11.5_{ab}	6.8_{b}	3.2_{b}	1.6_{ab}	27.5	12.2
MO	3.8_{d}	2.9_{c}	8.5_{a}	3.0_{b}	10.6_{ab}	4.2_{c}	3.2_{b}	1.5_{b}	22.3	87.0

EXP: Experiment CON: Control AB: Aba Egbira AT: Atikankan IG: Igbehin MO: Moshood

Table 8. Concentration of heavy metals in the tissues of *Jatropha mutifida* with and without EDTA treatment (mg/kg) on selected dumpsites

	Root		Steam		Leaf		Fruit		Shoot	
Cd	**Exp**	**Cont**	**Exp**	**Cont**	**Exp**	**Cont**	**Exp**	**Cont**	**Exp**	**cont**
AB	80.0_{a}	46.2_{a}	68.2_{a}	36.8_{a}	285.0_{a}	168.0_{a}	102.0_{a}	48.0_{a}	455.0	252.8
AT	82.4_{a}	50.6_{ab}	61.8_{a}	38.2_{a}	362.0_{ab}	162.0_{a}	100.0_{a}	45.0_{b}	523.8	245.0
IG	80.2_{a}	38.0_{b}	76.2_{ab}	30.0_{ab}	358.0_{ab}	172.0_{a}	96.4_{b}	43.0_{b}	530.6	245.0
MO	76.0_{a}	36.2_{b}	69.2_{ab}	68.2_{ab}	360.0_{b}	148.0_{b}	92.0_{b}	43.0_{b}	521.2	259.2
Cr										
AB	26.9_{a}	14.2_{a}	18.4_{a}	10.2_{a}	36.8_{a}	19.2_{a}	28.4_{a}	22.0_{a}	83.6	51.4
AT	26.6_{a}	14.0_{a}	18.2_{a}	10.0_{a}	35.2_{b}	19.0_{a}	28.2_{a}	20.1_{b}	81.6	49.1
IG	25.8_{b}	13.5_{b}	18.0_{a}	9.8_{b}	35.0_{b}	18.5_{b}	28.0_{a}	19.8_{ab}	81.0	48.1
MO	24.2_{b}	13.5_{b}	16.2_{b}	9.6_{b}	35.0_{b}	18.0_{b}	26.0_{b}	18.6_{b}	77.2	46.2
Cu										
AB	288.0_{a}	132.0_{a}	440.0_{a}	261.0_{a}	492.0_{a}	306.0_{a}	206.0_{a}	119.0_{a}	1138.0	686.0
AT	278.0_{a}	128.0_{a}	438.0_{a}	260.0_{a}	460.0_{a}	304.0_{a}	202.0_{a}	109.0_{b}	1130.0	673.0
IG	262.0_{b}	124.0_{b}	438.0_{a}	256.0_{a}	486.0_{ab}	289.0_{b}	192.0_{b}	116.0_{c}	1116.0	661.0
MO	258.0_{b}	122.0_{b}	415.0_{ab}	236.0_{ab}	482.0_{ab}	296.0_{c}	182.0_{c}	112.0_{d}	1079.0	644.0
Pb										
AB	89.6_{a}	52.5_{a}	106.0_{a}	92.7_{a}	192.0_{a}	192.0_{a}	138.0_{a}	86.0_{a}	436.0	370.7
AT	85.2_{ab}	50.6_{ab}	105.0_{a}	70.2_{ab}	186.0_{b}	186.0_{b}	126.0_{b}	82.0_{a}	417.0	338.2
IG	85.0_{ab}	49.2_{b}	129.3_{ab}	70.0_{ab}	182.0_{c}	182.0_{c}	124.0_{d}	80.0_{a}	435.3	332.0
MO	84.0_{ab}	48.2_{b}	122.0_{ab}	76.0_{b}	176.0_{d}	176.0_{d}	120.0_{c}	78.0_{ab}	418.0	330.0
Zn										
AB	7.0_{a}	3.8_{a}	9.6_{a}	4.6_{a}	14.8_{a}	6.8_{a}	4.6_{a}	2.1_{a}	29.0	13.5
AT	6.8_{a}	3.2_{b}	9.5_{a}	4.2_{a}	14.4_{a}	6.2_{b}	4.6_{a}	2.8_{b}	28.5	13.2
IG	6.4_{b}	3.0_{b}	9.6_{a}	5.8_{b}	13.6_{b}	6.4_{b}	4.5_{a}	2.1_{a}	27.7	14.3
MO	6.4_{b}	2.8_{c}	9.2_{b}	4.6_{a}	13.2_{b}	5.8_{c}	4.8_{a}	1.8_{c}	27.2	12.2

EXP: Experiment CON: Control AB: Aba Egbira AT: Atikankan IG: Igbehin MO: Moshood

Table 9. Concentration of heavy metals in the tissues of *Jatropha gossypifolia* with and without EDTA treatment (mg/kg) on selected dumpsites

	Root		Steam		Leaf		Fruit		Shoot	
Cd	**Exp**	**Cont**	**Exp**	**Cont**	**Exp**	**Cont**	**Exp**	**Cont**	**Exp**	**cont**
AB	70.3_{a}	40.0_{a}	48.1_{a}	18.6_{a}	279.0_{a}	112.0_{a}	89.7_{a}	36.7_{a}	416.8	167.3
AT	70.0_{a}	38.2_{a}	46.2_{a}	18.2_{a}	276.0_{a}	110.0_{a}	96.0_{ab}	32.2_{a}	418.2	202.4
IG	68.6_{b}	38.0_{b}	45.0_{b}	17.6_{ab}	258.0_{b}	98.0_{b}	96.0_{ab}	32.2_{ab}	399.0	147.8
MO	66.2_{c}	32.0_{c}	40.3_{c}	16.2_{ab}	242.0_{c}	96.0_{c}	95.2_{c}	30.0_{c}	377.5	142.2
Cr										
AB	16.2_{a}	6.8_{a}	18.0_{a}	11.2_{a}	26.0_{a}	16.2_{a}	18.6_{a}	10.8_{a}	62.6	38.2
AT	15.2_{ab}	6.7_{a}	17.0_{b}	11.0_{a}	25.6_{a}	16.0_{a}	18.4_{a}	10.8_{a}	61.0	37.8
IG	15.9_{a}	5.6_{b}	16.2_{b}	10.6_{a}	22.0_{b}	15.7_{b}	16.2_{b}	9.6_{a}	54.4	35.9
MO	14.8_{b}	5.3_{b}	16.0_{b}	10.2_{a}	20.2_{b}	15.3_{b}	16.8_{b}	8.6_{a}	53.0	34.1
Cu										
AB	264.0_{a}	106.0_{a}	388.0_{a}	306.0_{a}	422.0_{a}	246.0_{a}	152.0_{a}	98.0_{a}	962.0	650.0
AT	262.0_{a}	104.0_{a}	342.0_{a}	210.0_{a}	430.0_{a}	220.0_{a}	186.0_{ab}	96.0_{a}	958.0	630.0
IG	196.0_{ab}	111.0_{a}	356.0_{a}	168.2_{ab}	396.0_{ab}	210.0_{b}	146.0_{b}	70.0_{b}	898.0	448.0
MO	184.0_{ab}	98.0_{c}	308.0_{b}	162.0_{ab}	368.0_{c}	198.0_{b}	142.0_{c}	82.0_{d}	818.0	442.0
Pb										
AB	72.0_{a}	42.0_{a}	84.0_{a}	42.2_{a}	180.0_{a}	96.0_{a}	112.0_{a}	48.0_{a}	376.0	186.2
AT	70.0_{a}	40.0_{a}	84.2_{a}	42.0_{ab}	$156.0_{\mathbf{ab}}$	92.0_{ab}	110.0_{ab}	46.8_{ab}	350.0	180.8
IG	68.2_{b}	36.8_{ab}	80.2_{b}	36.0_{b}	160.0_{ab}	86.2_{b}	115.0_{b}	47.0_{ab}	355.2	169.2
MO	66.0_{b}	32.0_{b}	80.0_{b}	33.0_{c}	136.0_{b}	84.0_{b}	112.0_{a}	42.0_{b}	328.0	229.0
Zn										
AB	3.0_{a}	0.8_{a}	6.0_{a}	2.2_{a}	8.4_{a}	4.6_{a}	3.8_{a}	1.1_{a}	18.2	7.9
AT	2.8_{ab}	0.8_{a}	5.8_{b}	1.8_{ab}	8.0_{a}	4.6_{a}	3.3_{a}	1.3_{a}	17.1	7.7
IG	2.6_{ab}	0.7_{b}	5.2_{c}	1.6_{ab}	7.8_{b}	3.8_{b}	3.7_{a}	1.1_{a}	16.7	6.5
MO	1.2_{b}	6.0_{c}	2.8_{d}	9.6_{c}	4.6_{c}	3.2_{c}	3.4_{ab}	0.9_{b}	10.8	13.7

XP: Experiment CON: Control AB: Aba Egbira AT: Atikankan IG: Igbehin MO: Moshood

However EDTA and other synthetic chelators had been reported to have positive impact on the phytoextraction of heavy metals from contaminated sites [1,10]. The concentration of heavy metals in different tissues of plant on the four dumpsites varied significantly at p≤0.05 (LSD test), showing the effect of different soil conditions on these dumpsites. Also there were gradual reductions in the BF, TF and RR values in the order of moshood road < Igbehin street < Aba Egbira.

Table 10. BF, TF and RR values of heavy metals in *Jatropha curcas*

		BF		TF		RR	
		EXP	**CON**	**EXP**	**CON**	**EXP**	**CON**
Cd	AB	1.1	0.6	1.9	0.9	1.1	0.6
	AT	1.1	0.5	1.4	0.9	1.1	0.5
	IG	1.0	0.4	1.1	0.9	1.0	0.5
	MO	1.0	0.4	1.9	0.5	1.0	0.4
Cr	AB	0.9	0.6	0.9	0.6	0.9	0.6
	AT	0.5	0.1	0.8	0.5	0.5	0.1
	IG	0.5	0.1	0.6	0.4	0.5	0.1
	MO	0.5	0.1	0.7	0.3	0.5	0.1
Cu	AB	2.2	1.1	3.9	1.3	2.2	1.1
	AT	2.1	1.0	4.1	1.9	2.1	1.1
	IG	2.1	1.0	3.4	1.1	2.0	1.0
	MO	2.6	0.9	3.4	1.6	2.0	1.0
Pb	AB	1.7	0.9	2.2	1.3	1.8	1.1
	AT	1.3	0.8	1.9	1.7	1.8	1.0
	IG	1.6	0.7	1.7	1.2	1.6	1.0
	MO	1.5	0.6	1.8	1.1	1.6	1.0
ZnCrCuPbZn	AB	0.4	0.05	0.6	0.3	0.5	0.05
	AT	0.3	0.05	0.6	0.3	0.4	0.05
	IG	0.3	0.05	0.6	0.3	0.4	0.05
	MO	0.3	0.05	0.5	0.2	0.3	0.05

BF: Bioremediation Factor TF: Traslocation Factor RR: Remediation Ratio; AB: Aba Egbira AT: Atikankan IG: Igbehin Street MO: Moshhood Road

Table 11. BF, TF and RR values of heavy metals in *Jatropha gossypifolia*

		BF		TF		RR	
		EXP	**CON**	**EXP**	**CON**	**EXP**	**CON**
Cd	AB	1.1	0.5	2.9	1.2	1.2	0.5
	AT	1.2	0.4	2.9	1.3	1.3	0.5
	IG	1.1	0.4	2.8	1.3	1.3	0.5
	MO	1.1	0.3	2.7	1.4	1.2	0.4
Cr	AB	0.4	0.1	0.7	0.4	0.3	0.1
	AT	0.3	0.1	0.6	0.4	0.4	0.1
	IG	0.3	0.1	0.5	0.3	0.3	0.2
	MO	0.4	0.1	0.6	0.4	0.4	0.1
Cu	AB	2.1	1.1	2.8	2.2	2.2	1.0
	AT	2.0	1.0	2.7	2.1	2.1	1.0
	IG	1.8	1.0	2.6	2.2	2.0	1.0
	MO	1.8	0.9	2.4	2.5	2.0	1.0
Pb	AB	1.6	1.0	2.3	1.4	1.6	1.0
	AT	1.5	1.0	2.0	1.0	1.5	1.1
	IG	1.5	1.0	2.3	1.3	1.5	1.0
	MO	1.2	0.9	2.0	1.0	1.3	1.0
ZnCr	AB	0.6	0.05	0.5	0.2	0.8	0.1
CuPbZn	AT	0.5	0.04	0.4	0.2	0.9	0.1
	IG	0.4	0.03	0.4	0.1	0.7	0.1
	MO	0.4	0.03	0.3	0.1	0.7	0.1

BF: Bioremediation Factor TF: Traslocation Factor RR: Remediation Ratio; AB: Aba Egbira AT: Atikankan IG: Igbehin Street MO: Moshhood Road

Table 12. BF, TF and RR valuesof heavy metals in *Jatropha mutifida*

		BF		TF		RR	
		EXP	CON	EXP	CON	EXP	CON
Cd	AB	1.3	0.7	1.9	0.9	1.4	0.8
	AT	1.2	0.6	1.9	0.8	1.3	0.7
	IG	1.2	0.6	1.6	0.7	1.3	0.7
	MO	1.1	0.5	1.6	0.8	1.2	0.6
Cr	AB	0.8	0.2	0.9	0.6	0.8	0.2
	AT	0.7	0.1	0.8	0.5	0.8	0.2
	IG	0.7	0.1	0.7	0.4	0.7	0.1
	MO	0.6	0.1	0.7	0.4	0.7	0.1
Pb	AB	1.9	1.2	1.9	0.8	1.9	1.1
	AT	1.8	1.1	1.9	0.8	1.8	1.0
	IG	1.9	1.2	1.1	0.7	1.9	1.1
	MO	1.6	1.0	1.6	0.8	1.6	1.0
Pb	AB	1.9	1.2	1.9	0.8	1.9	1.1
	AT	1.8	1.1	1.9	0.8	1.8	1.0
	IG	1.9	1.2	1.1	0.7	1.9	1.1
	MO	1.6	1.0	1.6	0.8	1.6	1.0
Zn	AB	0.4	0.05	0.9	0.4	0.4	0.05
	AT	0.3	0.05	0.8	0.3	0.4	0.05
	IG	0.3	0.05	0.8	0.3	0.3	0.05
	MO	0.2	1.2	0.7	0.3	0.2	0.04

BF: Bioremediation Factor TF: Traslocation Factor RR: Remediation Ratio
AB: Aba Egbira AT: Atikankan IG: Igbehin Street MO: Moshhood Road

4. CONCLUSION

There were similarities in the phytoextraction capabilities of *J. curcas, J. gossypifolia* and *J. multifida*. This is evident as they could be applied as hyperaccumulators for targeting heavy metals such as Cd, Cu and Pb under EDTA assisted phytoextraction. EDTA was reported to have positive effects on metals bioavailability in soil and accumulation in the tissues of the three *Jatropha* species. The reduction in growth of plant on the application of EDTA characterized yellowing of leaves at the preflowering stage was offset by enhanced uptake of metals by EDTA. The heavy metals concentrations increased with the addition of chelators, especially for Cd, Cu, and Pb absorption in shoots. It is necessary to evaluate the effect of dosage of EDTA for future studies.

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COMPETING INTERESTS

Author has declared that no competing interests exist.

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