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Phytoaccumulation Potentials of *Tamarindus Indica*

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ABSTRACT: The concentrations of chromium, cadmium, copper, lead, zinc and manganese in *Tamarindus indica* plants growing on automobile contaminated sites (Dass Park and Mechanic village within Bauchi Metropolis were determined, in order to find out the phytoaccumulation potential of the plant for these metals. The weighted means of the various metals in the plant under investigation were observed to be higher than those obtained in the control site. The weighted mean of the metals in Dass Park was as follows: Cu (97.67mg/kg)> Zn (75.70mg/kg) > Mn (60.33 mg/kg) > (Pb 40.53 mg/kg) > Cr (3.52 mg/kg)> Cd (0.72 mg/kg). In Mechanic Village, a similar order was observed, with Cu (111.62 mg/kg)> Zn (64.93 mg/kg)> Mn (51.80 mg/kg)> Pb (48.77 mg/kg)> Cr (5.62 mg/kg)> Cd (2.34 mg/kg). The average concentration factors (CF) of the six elements in the *Tamarindus indica* studied at both contaminated sites were in the order: Cu (1.28)> Zn (0.38)> Mn (0.31)> Pb (0.27)> Cr (0.08)>Cd (0.06). Cadmium (Cd) has the highest translocation ratio, while Zn was observed to be the least. All the metals except Cd and Zn tend to accumulate mostly on the barks and roots of *Tamarindus indica* and this would therefore decrease their transfer probabilities to secondary consumers.

KEYWORDS: contamination, phytoremediation, heavy metals, large plants, mechanic workshop.

1 INTRODUCTION

Automotive maintenance facilities are considered to generate significant loads of hydrocarbons, trace metals and other pollutants, which can affect the quality of storm water runoff [1]. The extensive trace metal pollution of soil within and around Mechanic workshops implies that water bodies (surface and groundwater) within and away from the vicinity of the workshop may equally be polluted with trace metals due to continuous interactions between soil and water[2]. Heavy metal contamination of soil is now viewed world-wide as a global problem because metal pollutants are toxic, persistent and non-degradable in the environment [3], [4], [5], [6]. The removal of this persistent pollutant is therefore necessary but very difficult. The remediation of large volumes of such soil by conventional physicochemical technologies previously developed for small, heavily contaminated sites would be very expensive[7], [8].

A plant based technique called phytoremediation has been developed to ensure that the contaminants from the soil, sludge, sediments and waters are managed in an environmentally, yet cost effective way [9], [10], [11]. As in [7], many small herbs have been proven to accumulate heavy metal ions, the burden of harvesting and disposing these one season plants poses greater difficulties in applying phytoremediation. Hence, large plants with long period of life, soil covering and transpiration potentials could be the best choice for phytoremediation.

Generally, the use of phytoremediation is limited to sites with lower contaminant concentrations and contamination in shallow soils, streams, and groundwater. However, researchers are finding out that using trees (rather than smaller plants) allows them to treat deeper contamination. To effectively redeem contaminated automobile sites, the underground water and contaminants should therefore be within tree root depth, which is 10-20 feet below ground surface [12].

The aim of this research is to investigate the potential of *Tamarindus indica* plants (growing on two automobile sites) to accumulate cadmium, chromium, copper, lead, manganese and zinc.

2 MATERIALS AND METHODS

Dass Park and Mechanic village are two very importance automobile repair and maintenance sites within Bauchi metropolis, with more than fifteen years of operation. Dass Park is located along Dass road while Mechanic village is situated along Jos road. Geographically, Bauchi state lies between latitudes 9^0 30 N and 12^0 34' and longitude 8^0 5' E and 11^0 00' E of the Greenwich meridian. It occupies a total area of 549,259.01 sq. kilometres representing about 5.3% of the land mass of Nigeria. The state spans two vegetation zones namely Sudan and Sahel Savannah. Effective rains start in mid may or sometimes around early June and ends in late October. The dry season starts in October and ends in May. The average annual rainfall is between 1000mm and 1300mm.

2.1 SAMPLING AND ANALYSIS

Soil samples were randomly collected at ten (10) different drainage collection points along the direction of drainage in the respective mechanic villages at soil depth of 0 – 30cm using a soil auger. The samples were stored in polyethene bags. All the samples were collected between August and September, 2010. The samples from the two locations were homogenised to make a composite sample. A background sample or the control was similarly collected 500 m away from each mechanic village, against the direction of drainage. The soil samples from each of the study sites were conned and quartered several times before the required samples for analysis were obtained. The samples were then air dried, crushed in a mortar and sieved through a 2mm sieve. Three (3) replicate samples of 2.0g of the air-dried, ground and sieved sample were accurately weighed and digested in a 1:1 mixture of concentrated nitric acid and perchloric acid, by heating the mixture and the sample on a water bath in a fume cupboard. The mixture was heated to dryness; the residue was re-dissolved in 5cm3 of 2M HCl and filtered into plastic bottles [9], [10]. The digested samples were then subjected to analysis of the six metals using the Atomic Absorption Spectrophotometer (A Analyst 400, Perkin Elmer, U.S.A).

The leaves, barks and roots were collected from three randomly selected *Tamarindus indica* plants and stored in paper bags. Root tissues were sampled from what was considered to be the surface roots of these plants. The plant samples were washed thoroughly with running tap water to remove the soil particles from the leaves, barks and roots. The samples were then cut into smaller pieces and oven- dried at 60^oC for three (3) days. The dried samples will be ground to powder and stored in labelled polythene bags [10], [13]. Three replicate samples (the leaves, bark and roots) and six different samples of the whole plant *(T. indica*) were digested with a mixture of conc. nitric acid and perchloric acid. 1.0g of the ground dried plant samples were placed in a small beaker and 10ml of the conc. HNO_3 was added to the beaker and allowed to stand overnight. The contents were heated on a hot plate in a hood until the production of red NO_2 fumes has ceased. The beaker was cooled and 3.5ml of 70% $HClO_4$ will be added. The mixture was then heated and allowed to evaporate to a small volume. Digested samples were diluted to 50ml with distilled water [14]. Each sample extract were then placed in plastic bottles, before subjecting them to analysis of the six metals using the Atomic Absorption Spectrophotometer (A Analyst 400, Perkin Elmer, U.S.A).

3 RESULTS AND DISCUSSION

Table 1 shows the concentration of heavy metals in *Tamarindus indica* plants tissues and the weighted mean concentration in the various study sites. The transfer ratios of the heavy metals from the root to the leaves and the bark are given in **Table 3.**

Table 1. Accumulation of Average Heavy Metals in Tamarindus indica (mg/kg)

Metal	DASS PARK				MECHANIC VILLAGE				CONTROL SITE				Normal range in plants
	Leaves	Bark	Root	Weighted mean	Leave	Bark	Root	weighted mean	Leave	Bark	Root	Weighted mean	
Cd	1.73^{A}	0.31^{B}	0.11^{C}		3.53^{A}	3.15^{B}	0.35^{C}		ND	ND	ND	ND	
	±0.22	±0.04	±0.06	**0.72**	±0.14	±1.35	±0.06	**2.34**					0.1-2.4^{D}
Cr	0.22^{A}	7.16^{B}	3.17^{C}		0.22^{A}	10.30^{B}	6.33^{C}		0.017	0.510	0.150		
	±0.03	±0.04	±0.06	**3.52**	±0.02	± 0.71	±0.28	**5.62**	±0.08	±0.08	±0.13	**0.23**	0.03-14^{E}
Cu	27.80^{A}	133.20^{B}	132.00^{B}		31.10^{A}	163.71^{B}	140.10^{C}		10.23	37.65	15.85		
	±6.08	±10.90	±13.00	**97.67**	±5.21	±17.70	±12.32	**111.62**	±3.62	±5.21	±3.07	**21.34**	5 – 20^{E}
Pb	16.07^{A}	45.47^{B}	60.07^{C}		29.97^{A}	57.57^{B}	58.75^{B}		7.433	21.47	41.22		
	±0.97	±0.68	±8.12	**40.53**	±1.33	±2.98	±3.19	**48.77**	±0.80	±1.40	±3.66	**23.34**	0.2 -20^{E}
Mn	31.10^{A}	72.97^{B}	76.88^{B}		37.12^{A}	47.53^{B}	0.730^{C}		8.533	30.83	47.32		
	±0.82	±1.79	±2.64	**60.33**	±3.19	±1.80	±0.75	**51.80**	±1.60	±0.61	±3.73	**28.89**	20-1000^{D}
Zn	76.35^{A}	69.27^{B}	81.43^{A}		53.92^{A}	50.38^{A}	90.53^{B}		41.48	44.85	53.38		
	±1.13	±0.69	±4.88	**75.70**	±6.88	±4.20	±54.80	**64.93**	±5.33	±04.23	±4.80	**46.57**	1-400^{E}

(D and E were obtained from [15] and [10] respectively, ND – Not detected, Values ($^{A, B, C}$) within a row for each part of the plant, with different superscripts are significantly different ($p< 0.05$).

3.1 ACCUMULATION OF METALS IN *TAMARINDUS INDICA* ON THE CONTAMINATED SITES

The result in Table 1 shows that the weighted means of the metals in the whole plant in Dass Park (DP) is in the order: Cu (97.67mg/kg)>Zn(75.70mg/kg)>Mn(60.33mg/kg) >Pb(40.53mg/kg) >Cr(3.52mg/kg)>Cd(0.72mg/kg), while in the Mechanic Village (MV), the weighted mean is in the order: Cu (111.62mg/kg) >Zn(64.93mg/kg) >Mn(51.80mg/kg) >Pb (48.77mg/kg) >Cr(5.62mg/kg)>Cd(2.34mg/kg). The order of the accumulation of the metals in this tree in the study sites, were observed to be similar.

The values of the metals accumulated in the plant in the contaminated and control sites were within the normal range in plants except Cu and Pb, reflecting the high level of enrichment of these metals (Cu and Pb) in these sites. The little increase in the concentration of Cu and Pb, especially, the control site could be attributed to the fact that soils from urban area (including farm lands) could be 5-10 times as high in Cu due to combustion of wood products, fossil fuels and waste incineration with the area. Also, Pb in urban soils could be derived from abraided tyres materials, coal, plastics, insecticides and car batteries, paints and wash off from gutters containing wind borne dust. Also Pb in leaf materials can be due to foliar uptake [15].

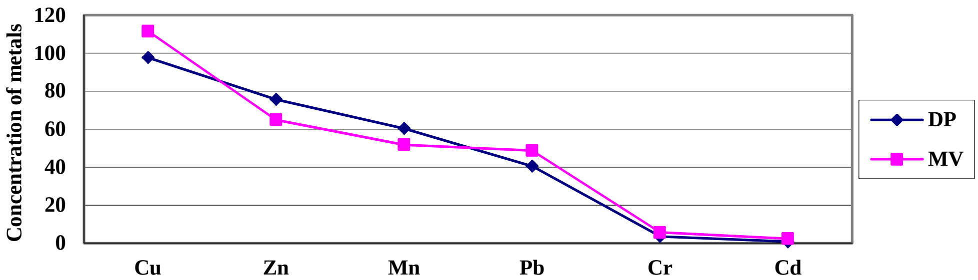

Fig.1 Accumulation trend of the Metals in T. indica on Automobile

Fig. 1 shows that in the contaminated sites, a decreasing trend of accumulation of the metals from Cu to Cd for the plant was observed. In both contaminated sites, it was observed that the order of metal concentration showed that $Cd_{leave}>>Cd_{bark}> Cd_{root}$, while $Cr_{bark}>Cr_{root}>>Cr_{leave}$. In DP, $Cu_{root}= Cu_{bark}> Cu_{leave}$ while $Cu_{bark}>Cu_{root}>Cu_{leave}$ in MV. In DP, $Pb_{root} > Pb_{bark} > Pb_{leaves}$, while in MV, $Pb_{root} = Pb_{bark} > Pb_{leaves}$

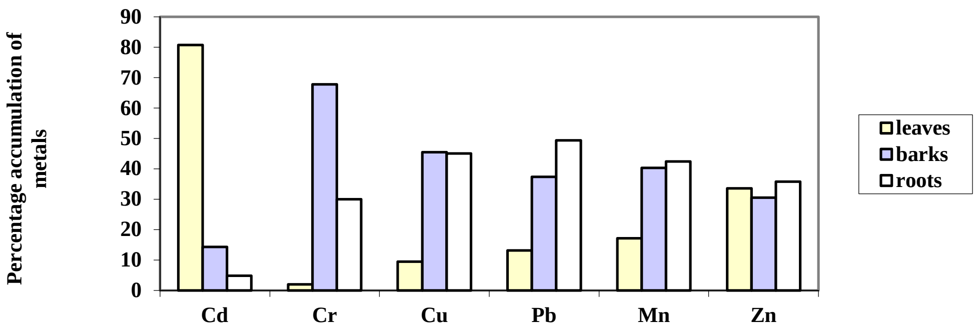

Fig.2. Percentage accumulation of metals by each plant component of T. indica in Dass site

Fig. 2 shows that in DP, 80% of the Cd absorbed by this plant is stored in the leaves, while in Fig. 3; the Cd accumulation was more than 50% in the leaves in MV.

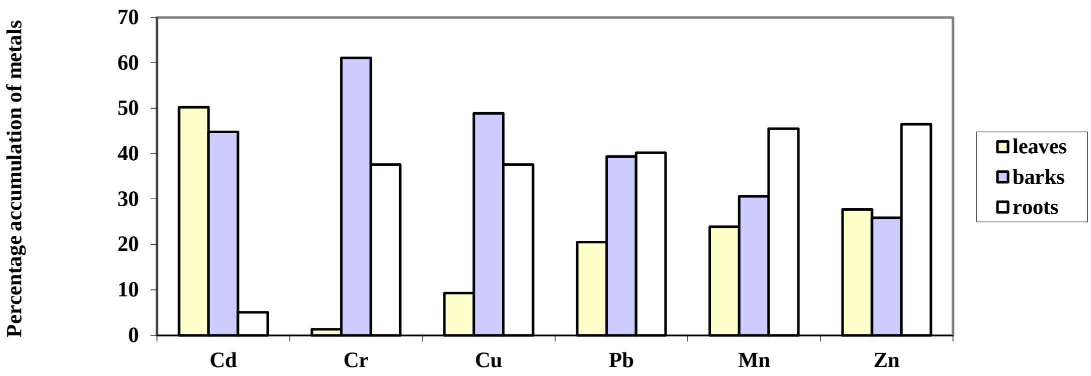

Fig. 3. Percentage accumulation of metals by each plant component of T. indica in Mechanic village

The distribution pattern of heavy metal in this tree indicated that all the metals except Cd and Zn, accumulated in the barks, followed by the root tissues. This shows that the tree has the capacity to be extremely tolerant to these metals. It has been noted that in trees, the heavy metals concentration in the bark is generally found to be higher than in the wood of the stem [16].

3.2 TRANSLOCATION OF HEAVY METALS IN *TAMARINDUS INDICA*

Translocation ratio (TR) of metal is the ratio of the concentration of heavy metal in the aerial parts of a plant to the concentration of the heavy metal in the root $[HM]_{aerial}/[HM]_{root}$. Translocation ratio gives a picture of the mobility of metals from the aerial parts of the plant [13]. In table **2**, the average translocation ratio from the root to leave for this tree was in the order: Cd>Pb>Mn>Cu>Cr>Zn. In the bark, the order changed to Zn<Mn<Pb<Cu<Cr<Cd. [15] and [16] noted that generally Cr, Cu and Pb are translocated to a lesser extent to the plants top compared to Mn and Zn. Cr accumulation in the leaf is quiet low or almost negligible when compared to stem and roots [17]. This could explain the low level of Cr in the leaves of this plant. In this study, no significant difference was observed between the translocation ratio of Cr/Cu and that of Zn from root to leaves while for Pb; the TR was also not significantly different when compared to Mn. In the bark each metal exhibited different extent of translocation ratio.The differences between these results and those reported by other studies may be because the rate and extent of movement of metal ions within plants do not only depend on the metal concern, but also on the plant organs and age of plant [16]. In this plant, Cd was observed to have the highest translocation ratio, showing that Cd is more mobile in plants (Table 2).

Table 2. Average translocation ratio of detected metals and concentration factor of Tamarindus indica in the study sites

Metal	Average Translocation Ratio (TR)		Average Concentration Factor (CF)
	leaves	Bark	
Cd	13.67±0.06	5.92±0.32	0.06±0.06
Cr	0.48±0.01	1.94±0.45	0.08±0.03
Cu	0.48±0.08	1.09±0.11	1.28±0.63
Pb	0.68±0.07	0.87±0.16	0.27±0.05
Mn	0.54±0.07	0.81±0.20	0.31±0.04
Zn	0.31±0.07	0.70±0.21	0.38±0.01

3.3 Ability Of *T. Indica* To Absorb Metal In The Contaminated Sites

The concentration factor (CF), is the ratio of metal in the plant to the concentration of metal in the soil. It gives an idea of the ability of a plant to accumulate metals absorbed from the soil and reveals the accumulation pattern in the plants [13]. The average concentration factor (CF) for *T. indica* indicates that the order increased thus: Cd<Cr<Pb<Mn<Zn<Cu (**Table 2**). Except for Cu (CF= 1.28), the CF for all the other metals exceeded 0.1 but were lower than 0.5, though their CF values show moderate accumulation except Cd (CF=0.06) and Cr (CF=0.08). The average CF values for Cu, Pb and Zn obtained in this study were observed to be higher than those reported by some other researchers, while they reported a higher CF value for Cd [18]. From these results, it is obvious that *T. indica* exhibited the capacity to absorb high amount of Cu and moderate amount of Zn.

3.4 Pearson Bivariate Correlation Coefficient For Metals In *T. Indica* (Whole Plant)

Table 3 shows that Cd negatively correlated with Cu (r= -0.819; p<0.85). A strong relationship exists between Pb and Mn (r= 0.892; p<0.05). This indicates that an increase in the concentration of Cd in this plant can lead to a decrease in Cu and vice versa. Likewise, increase in Pb would result in an increase in Mn.

3.5 Heavy Metal Concentration In The Study Sites

The heavy metal concentrations in the two mechanic workshops were well over those of the control site (**Table 4**). Although the metal concentrations in this present study were lower than those reported by [2], except for Cd and Cr, the present results obtained for Cd, Cr, and Pb are similar to those reported for automobile workshops in Akure [19]. The order of abundance of the metals in Dass park and Control site were Zn>Mn>Pb>Cu>Cr>Cd while in the Mechanic village (M.V), the order changed to Mn>Zn>Pb>Cu>Cd>Cr. The order in the M.V was similar to results obtained by [2] and [19].The values obtained in the contaminated and control sites in this study are within the normal range in soils except for Cd. The enrichment of Cd and Cu in both automobile sites were significantly different, while Cr, Pb, Mn and Zn were not. The accumulation of Cd and Cu were higher in the Mechanic Village.

Table 3. Pearson Bivariate Correlation Coefficient for Metals in T indica (whole plant)

		Cd	Cr	Cu	Pb	Mn	Zn
Cd	R	1					
	P						
Cr	R	.255	1				
	P	.626					
Cu	R	.819(*)	-.479	1			
	P	.046	.336				
Pb	R	-.642	.030	.305	1		
	P	.170	.955	.556			
Mn	R	-.342	-.075	.188	.892(*)	1	
	P	.507	.887	.721	.017		
Zn	R	-.144	-.621	.170	-.448	-.606	**1**
	P	.785	.189	.748	.373	.202	

(Correlation is significant at the 0.05 level)*

Table 4. Heavy Metal Enrichment (mg/kg) of Soils in the Automobile contaminated sites and Control site

Metal	Cd	Cr	Cu	Pb	Mn	Zn
Dass Park	16.90 [a]	62.03[a]	73.60[a]	168.6[a]	177.50[a]	197.40[a]
	±3.35	±2.63	±11.30	±3.27	±2.29	±2.29
Mechanic Village	31.35[b]	55.50[a]	90.20[b]	160.30[a]	184.41[a]	175.72[a]
	±5.33	±5.47	±9.25	±10.50	±12.00	±14.60
Control site	1.52	9.47	24.35	37.57	44.77	72.70
	±0.57	±0.83	±3.60	±3.89	±9.42	±13.60
Normal range in soil	0.01-2[ж]	5-1500 [жж]	2-250 [жж]	2-300 [жж]	20-10,000[ж]	1-900 [жж]

([ж] Alloway, 1996, [жж] Oyelola et al., 2009), Values within a column with different superscripts are significantly different (p< 0.05).

4 Conclusion

The study shows that *Tamarindus indica* can highly accumulate Cu and Pb, while moderately accumulating Mn and Zn (on the average) compared to the other metals. This could be useful for the bio-recovery of these metals, especially Cu and Pb. Considering the kind of activities taking place in mechanic workshops, large plants should be planted in and around these workshops to help in the litigation of heavy metals released into the environment from these workshops, prevent erosion and provide shade in these sites.

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