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PHYTOREMEDIATION OF POTENTIALLY TOXIC ELEMENTS IN WASTE DUMPSITE SOIL BY *Albizia lebbeck* L. Benth SEEDLINGS

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ABSTRACT

Environmental problems caused by solid wastes are well noted. The non-availability of land and need to re-use the waste dumpsite due to urbanisation and developmental growth has called for their rehabilitation, This study investigated the ability of *Albizia lebbeck* to accumulate and transfer potentially toxic elements (PTEs: Cu, Zn, Pb, Cd and Co) into their tissue parts for remediation of waste dumpsite. Pots experiment consisting of three treatments: T1 (2kg of Ajakanga dumpsite soil), T2 (2kg of Lapite waste dumpsite soil and T3 (2kg of topsoil as control), replicated ten times in a completely randomized design were used. The study was carried out for a period of 12 Weeks After Transplanting (WAT). Concentrations of the PTEs in soils before and after experiment as well as those of the plants were determined using standard methods. Data were assessed using bioaccumulation (BAF) and translocation factors (TF). The reduction in the mean concentration (mg/kg) of PTEs in soil before experiment: Cu (22.10-112.02), Zn (18.26 – 92.09), Pb (9.05- 42.17), Cd (0.59-5.29) and Co (1.08 -7.99); and after the experiment: Cu (11.25-78.99), Zn (8.11 – 50.86), Pb (5.05- 20.98), Cd (0.33-1.89). Co (0.66 -4.81) indicated the uptake of this elements by *Albizia lebbeck* seedlings. The BAF (0.21-1.06) and TF (1.04 -1.29) values of PTEs in *Albizia lebbeck* seedlings indicate its potential as a phytoexctrator plant. Thus, *Albizia lebbeck* through urban forestry can be used to reduce the toxicity of the studied elements in waste dumpsite.

Keywords: Contamination, Bioaccumulation, Phytoexctraction, Rehabilitation, Forestry

Introduction

Waste dumpsite is an enormously erratic and heterogeneous environment, as apparent from the variety of refuse composition with respect to location and time. Wastes deposited in a dumpsite consist of a wide range of organic substances that can be natural and xenobiotic (Nagendran, 2006). Municipal solid wastes (MSW) are dumped in well designed sanitary in many developed countries while in developing countries like Nigeria, wastes are dumped in uncontrolled and hysterical manners without any preventative measure to deal with gas emissions and leachate generation, which pose a threat to the environment.

Usage of dumpsites for farming has become a regular practice in urban and sub-urban centers in Nigeria due of their richness in organic matter and other elements from waste decomposition which enhance soil fertility (Cunningham *et al*., 1996; Akintola, 2014). These wastes often contain different heavy metals in different concentration levels. Some heavy metals such as As, Cd, Hg, Pb is particularly hazardous to plants, animals and humans (Alloway, 2001, Singh *et al.*, 2011). Domestic wastes consisting of heavy metals as As, Cd, Cu, Fe, Hg, Mn, Pb, Ni, and Zn may end up in the soils as a result of leaching from the dumpsite (Akintola *et al.*, 2019). Plants grown on a soil polluted with domestic, agricultural or industrial wastes can absorb heavy metals through their root and transfer them to its different tissue parts (Akintola, 2014). These plants when consumed by human may become harmful to health as a result of the accumulation of the potential toxic elements (PTEs) from the decomposed wastes in the dumpsite. Food contamination by PTEs has become a challenge for producers and consumers. The main sources of PTEs to vegetable crops are their growth media (soil, air, nutrient solutions) from which these elements are taken up by the roots and transfer to other parts (Lokeshwari and Chandrappa, 2006). Accumulation of heavy metals by crops or plants from contaminated soils has become a critical issue as their accumulation in crops may affect human health through the food chain (Gupta, 1995). Dumpsite soils used for growing of plants have shown to possess enhanced heavy metal concentrations due to the anthropogenic effect of the wastes on the environment (Amusan *et al.,* 2003). Potentially toxic elements comprise of heavy metals such as arsernic (As), cadmium (Cd), lead (Pb), zinc (Zn), chromium (Cr), Copper (Cu) and non metals that may be noxious and detrimental to human and other organism even at low concentrations (Nieder *et al.,* 2018; Rocco *et al.,* 2018). Soil contamination by these noxious elements from anthropogenic activities is one of the factors that affect the life in soils (Su, 2014). These elements have high density and high relative atomic weight, metallic properties such as ductility, malleability, conductivity, ligand specificity (Algreen *et al.*, 2012). Elements such as Co, Cu, Fe, Mn, Co, Ni, and Zn are useful when they are in adequate amount but can be toxic if they are in excess in any environmental media such as plant soil and water (Alloway, 2001). Likewise, elements such as Pb, Cd, and Cr can be hurtful to crops, humans, and animals.

Natural or planted vegetation on a dumpsite has an imperative role in controlling erosion and eliminating contaminants, leachate treatments as well as adding physical value to the site (Maurice, 1995). Although, phytoremediation of lands contaminated with a range of contaminants are existing (Siciliano and Germida, 1998; Schwitzguebel *et al.,* 2002), the usage of this method for remediation and rehabilitation of municipal solid waste dumpsites has been given inadequate attention. *Albizia lebbeck* commonly known as Woman's tongue belongs to the Fabaceae family; it is a deciduous, perennial and medium legume tree. The seeds of this tree have been shown to be useful for removal of metals and other pollutants in solution through adsorption (Zakari and Audu, 2021). The present study thus assessed the remediation potential of *Albizia lebbeck* seedlings for solid waste dumpsite soils.

Materials and Method

A pot experiment was carried out in Nursery 'A' of Forestry Technology Department, Federal College of Forestry Ibadan, Oyo State. The area lies between Latitude (7^{o}26'N - 7^{o}28'N) and Longitude (3^{o}51'E-3^{o}54'E). Topsoils were collected from Ajakanga and Lapite solid waste dumpsites in Ibadan, Oyo state, Nigeria. Ajakanga dumpsite is an open waste disposal site located between latitude (7°17´N - 7°19´N) and longitude (3°50´E to 3°53) within Oluyole local government while Lapite dumpsite is located between latitude (733´ 30´´ N to 7 34´ 30´´N) and Longitude (3° 53´ 30´´E to 3° 55´ 30´´ E) in Ibadan, Oyo State, Nigeria.

The climate of the area is tropical. The annual rainfall ranges from 1400mm – 1500mm and average relative humidity of about 65%, the average temperature is 31.8^{0}C. The topsoil was collected from Forestry technology department demonstration plots within Federal College of Forestry, Ibadan, Nigeria.. The soils that were collected from three different locations were air-dried and sieved with 2mm diameter mesh. The treatments were designated as T1 (2kg of Ajakanga dumpsite soil), T2 (2kg of Lapite waste dumpsite soil and T3 (2kg of control soil). The seeds were planted in a constructed germination bed at the nursery for 4 weeks, after which they were transplanted into polythene pots. The experiment was laid out in a Completely Randomized Design and the treatments were replicated ten times making a total of 30 potting media. Watering was done twice a day and regular weeding was also carried out when necessary.

At the end of 12 weeks of pot experiment after transplanting, seedlings were measured for seedling heights (cm), leaf production, stem diameter (mm). The soil used before and after the experiment analyzed for PTEs (Cu, Zn, Pb, Cd and Co). Soil samples were air-dried, ground with mortar and pestle, and sieved through 1 mm mesh before analysis. Plant samples (shoots and roots) were also air-dried and ground. Soil and plant (shoots: stem and leaves; and roots) samples were analysed for Cu, Zn, Pb, Cd and Co using Atomic Absorption Spectrophotometer (AAS). Two (2) g of soil samples were digested with 10 ml of 0.30 HCl and 3.50 ml of 0.65 HNO_3 at 150°C for 1 hour 30 minutes. The solutions were heated at 230°C for 30 minutes. The digestion tubes were then removed and allowed for cooling before washing the contents into 50 ml volumetric flasks. The digestion of 0.5 g plant samples was also done with 5 ml of the acid mixture using the same procedure. The analyses were done in triplicate and the readings were taken.

Bioaccumulation factor (BAF) and Translocation factor (TF) were calculated using the formula of Yadav *et al*. (2009) as

$$\text{Bioaccumulation factor (BAF)} = \frac{\text{heavy metal concentration in plant}}{\text{heavy metal concentration in soil}} \dots \text{ Equation 1}$$

$$\text{Translocation factor (TF)} = \frac{\text{heavy metal concentration in shoot}}{\text{heavy metal concentration in root}} \dots \text{Equation 2}$$

Data were analyzed using one-way analysis of variance (ANOVA) and mean were separated using Duncan Multiple Range Test (DMRT).

Results and Discussions

Growth response of *Albizia lebbeck* seedlings

The effect of dumpsites soil on the growth performance of *Albizia lebbeck* seedlings at 12th weeks after transplanting (WAT) is presented in Table 1. The seedlings grown with T_1 (2kg of Lapite dumpsite soil) had the highest mean value of 25.22cm in term of seedling height, followed by T_2 (2kg of Ajakanga dumpsite soil) with mean value of 18.42cm while T_3 (the control) had the least mean value of 10.89cmat P=0.05

Table 1: Mean values of growth performance of *Albizia lebbeck* seedlings at 12th WAT

Treatment	seedling height cm	stem diameter mm	leaf production
T_1	25.22^a	0.88^a	1.46^b
T_2	18.42^b	0.62^b	1.42^b
T_3	10.89^c	0.35^c	3.53^a

Mean with the different letters within the same row are significant different from each other at P=0.05. WAT: weeks after transplanting

Also, seedlings grown with T_1 was with highest mean value of stem diameter (0.88mm), followed by T_2 with the mean value of 0.62 while T_3 had the lowest mean value of 0.35mm at P=0.05. However, highest mean value of leaf production was observed in T_3 (3.53) while mean values of leaf production of seedlings from T_1 (1.46) and T_2 (1.44) were lower and not significant different from each other.

The higher values of the seedling height and stem diameter from T_1 and T_2 might be accredited to the richness of the soil in organic matter content and other nutrients from waste decomposition which enhances plant growth (Cunningham *et al*., 1996). Also, the lowest values of leaf production recorded in T_1 and T_2 are ascribed to the impact of high concentration of the potentially toxic elements in the soil. This is according to the report of Peralta-Videa *et al.* (2009) that elements such as Cu, Zn, Cd, Co are essential micronutrients for plant growth and development but when in excess or deficient can affect the physiological processes such as photosynthesis, respiration, plant structure among others. This finding agreed with the similar work conducted by Akintola *et al*. (2019) on remediation potential of *Adansonia digitata* seedlings grown in sewage sludge contaminated by heavy metals.

Potentially toxic elements (PTEs) in potting media

Table 2 presents the PTEs concentrations in the growing media before and after the experiment. Concentrations of the elements in soil before experiment were found to be significantly higher than after the experiment at P=0.05. The high concentrations of Cu, Zn, Pb, Cd and Co in T_1 and T_2 in dumpsite soils can be attributed to the decomposition of wastes.

Table 2: Mean concentration values of PTEs in soil before and after the experiment

Treatments	Experiment	PTEs in mg/kg				
		Cu	Zn	Pb	Cd	Co
T1	Before	112.02[a]	92.09[a]	42.17a	5.29[a]	7.99[a]
	After	78.99[b]	50.86[b]	20.98[b]	1.89[b]	4.81[b]
T2	Before	88.22[a]	48.11[a]	36.22[a]	2.41[a]	5.08[a]
	After	54.41[b]	25.66[b]	14.99[b]	0.89[b]	3.01[b]
T3	Before	22.10[a]	18.26[a]	9.05[a]	0.59[a]	1.08[a]
	After	11.25[b]	8.11[b]	5.09[b]	0.33[b]	0.66[b]

Mean with the different letters within the same row are significant different from each other at P=0.05. WAT: weeks after transplanting

Concentration of potentially toxic elements (PTEs) in *Albizia lebbeck* seedlings

The concentrations of PTEs in *Albizia lebbeck* seedlings' parts are shown in Table 3. The shoots contained more concentrations of the studied elements than the roots; this indicates that *Albizia lebbeck* seedlings have the ability to uptake the elements from the soils into the roots and shoots. The mean values of the shoot and roots were not significantly different from each other at P=0.05. Plants have been used to define metal hyperaccumulators in soils with low metals concentration of 10mg /g in their tissue parts (Sun *et al*., 2009 and Thakur *et al*., 2016).

Table 3: Mean concentration values of PTEs in *Albizia lebbeck* seedlings parts

Treatments	Seedling parts	PTEs in mg/kg				
		Cu	Zn	Pb	Cd	Co
T1	Shoot	8.57	6.23	3.11	0.51	1.87

	Root	6.92	5.99	2.81	0.48	1.45
T2	Shoot	7.01	5.36	3.01	0.18	1.68
	Root	5.66	4..51	2.67	0;16	1.37
T3	Shoot	3.56	2.18	2.21	0.11	0.36
	Root	2.79	1.87	1.88	0.10	0.31

Potential of Albizia lebbeck seedlings for removal of PTEs in soils

Potential of plants to accumulate metals from contaminated soils is very crucial due to likelihood of using the plants as biomonitors or remediators. Bioaccumulation and translocation factors of metals in plant tissues are important in assessing the ability and effectiveness of plant to remove toxic substances from polluted soils (Sasmaz and Sasmaz, 2009; Akintola and Bodede, 2019a). Table 4 presented the values of BAF and TF of PTEs in *Albizia lebbeck* seedlings.

Table 4: Values of Bioaccumulations (BAF) and Translocation factors (TF) of Studied PTEs in *Albizia lebbeck* seedlings parts

Treatments	Factors	PTEs in mg/kg				
		Cu	Zn	Pb	Cd	Co
T1	BAF	0.20	0.24	0.28	0.52	0.69
	TF	1.24	1.04	1.11	1.06	1.29
T2	BAF	0.23	0.39	0.38	0.38	1.01
	TF	1.24	1.18	1.13	1.23	1.23
T3	BAF	0.56	0.50	0.80	0.64	1.06
	TF	1.27	1.17	1.18	1.10	1.16

The range values of BAF of the studied PTEs in T_1 (0.21 – 0.69) and T_2 (0.23-1.01) were lower in seedlings grown in dumpsite soils when compared to T_3 (0.56-1.06). This is ascribed to the higher concentration of the PTEs in the dumpsite soil, as it will take a longer time for the plants to accumulate higher amount concentrations of the elements. This also explained their higher accumulation in plants grown in T3.

Thus, the ability of the plants to accumulate these elements relies on their concentrations in the soil, time and other factors (Brady and Weil, 2002). Translocation factors (TF) of PTEs from the soil to Albizia *lebbeck* seedling's parts from the three treatments ranged from 1.04 -1.29. TF value more than 1 show that Albizia *lebbeck is* suitable for phytoextraction due to its capacity to translocate metals from root to shoot (Kumar *et al.*, 2005; Yoon *et al.*, 2006; Akintola *et al*., 2021). Since, the seedling can uptake the elements even at low concentration, accumulate many elements concurrently, have high growth rate and is tolerant to the toxic element (Accioly and Siqueira, 2000) thus, *Albizia lebbeck* can be used as phytoremediator for contaminated soil.

Conclusion

The efficiency and prospective of Albizia *lebbeck* to accumulate and transfer the potentially toxic elements into their tissue parts from waste dumpsite have been studied. Thus *Albizia lebbeck* through urban forestry can be used to clean or rehabilitate soils that are contaminated with the studied potentially toxic elements. .

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