Potential of *Ricinus communis* L. For Removal of Heavy Metal in Contaminated Soil

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ABSTRACTS: Heavy metal contamination has become a serious ecological problem due to its toxic effects on soils, plants and human. Experimental study was conducted on dumpsite soil to assess the potential of *Ricinus communis* to accumulate heavy metals from the soil using bioconcentration (BCF) and tanslocation factors (TF). Heavy metals concentration (mg/kg) in dumpsite and control soil before planting were Mn (50.68- 220.08); Zn(29.01- 135.56); Cu (8.92- 86.88), Pb (5.88-48.86), Ni (3.01-7.99) and Co (1.78-6.88) while the concentration in soils after planting were Mn(29.89- 135.21); Zn (15.11-88.21); Cu (3.89-50.22), pb (3.68-31.56), Ni (1.22-3.56) and Co (0.67-2.68) in Mg/kg.*Ricinus communis* showed BCF greater than 1 for Ni and Co and less than 1 for Mn, Cu, Zn and Pb while TF is greater than 1 for all the determined heavy metals. The dumpsite soils have higher heavy metal concentration than the control soil. The levels of heavy metals concentration in soils and plants are in the order of Mn> Zn> Cu> Pb> Ni. Significant reduction (P<0.05) was observed in the heavy metal concentrations in the soils before and after planting indicating their accumulation in the plants. Results of this study indicate the accumulation of heavy metals in*Ricinus communis* plants and its potential for effective removal of Cu, Zn, Pb, Ni, Co and Mn from the dumpsite soils.

Increase in population has led to rapid urbanization growth and industrialization development in most cities of the world. This has led to increase in the quantities of solid wastes generated and has constituted a major environmental problem such as heavy metal contamination. Heavy metal contamination from solid wastes has become a severe ecological problem with increasing interruption of natural biogeochemical cycles due to their non-biodegradable nature (Akintola, 2014; Gworek *et al*., 2016; Zhu *et al*, 2016). The influence of human activities on the ecosystem has been recognized as one of the major cause of heavy metal contamination (Mazur *et al.,* 2015; Yin *et al.,* 2016). Consequently, heavy metal contamination has become a significant threat to the environment and human health due to their slow biodegradability, easy bioaccumulation and hightoxicity (Akintola and Bodede, 2019a; Adamcova *et al.,* 2019). Solid wastes can decompose wide varieties of contaminants which can extensively affect the environment and human health (Sing *et al.,* 2011). The improper management of waste dumpsites in many countries of the world has led to heavy metals contamination due to leachates that emanate from the decomposition of the deposited wastes (Akintola, 2014; Bartkowiak *et al.,* 2016, Famuyiwa *et al.,* 2018).

Higher levels of heavy metal concentrations in soils from dumpsites and their ecological effects has been reported by several researchers (Akintola and Bodede, 2019b; Famuyiwa *et al.,* 2018, Hu *et al.,* 2018; Akintola *et al*., 2020). Ajakanga dumpsite and its environ has been reported to have elevated concentrations of heavy metals due to anthropogenic influence of the wastes (Oguiseju *et al.,* 2015; Ganiyu *et al*., 2016, Ewemoje *et al*., 2017; Akintola and Bodede 2019a). Akintola and Bodede (2019a) in their study indicated no to low heavy metal pollution level in the vicinity of Ajakange dumpsite and no probable health risk was observed as the total hazard index of all the heavy metals was less than one. However, they indicated rremediation techniques should be applied to reduce the mobility of heavy metals in the contaminated soils and to decrease the likely uptake of these heavy metals by plants and oral ingestion by human in the study area. Remediation of polluted soils is a demanding task, however several methods such as mechanical removal and chemical engineering has been used but they are   costly and only useful depending on the structure and fertility of the soil (Gaur and Adholeya, 2004). Using of plants for removal of pollutants from the soil and water is presently used as a substitute for soil clean-up

(Bauddh *et al.,* 2015). Since they respond to higher concentration of contaminants such as heavy metals by different means of indication, exclusion or accumulation of elements thus, phytoremediation has the advantage of using the selective uptake potential of some plants through the root and rhizomes to remove or modify contaminants from the environment (Nawrot *et al.,* 2019). Phytoremediation is a traditional method that is economically suitable, feasible, eco-friendly and improves the soil fertility by releasing various organic compounds. This study investigated the potential of *Riccinus communis* plants for removal of heavy metals in soils from Ajakanga dumpsite in Ibadan, South western Nigeria.

MATERIALS AND METHOD

Study area: Ajakanga dumpsite is an open waste disposal site located between 7°18´41.32″ N (latitude) and 3°50´29.34″ E (Longitude) within Oluyole local government, Ibadan south-western Nigeria (Akintola and Bodede, 2019a). Increase in population and rapid urbanization has opened the dumpsite to build up areas. The vegetation is tropical rain forest with thick undergrowth. The study area is drained by River Ona and its tributaries. The drainage pattern is dendritic. Ajakanga waste dumpsite and its environs are underlain by biotite-hornblende gneiss, migmatite gniess and quartzite (Ogunseiju *et al*., 2015). Previous studies conducted in this area revealed elevation increased in heavy metals concentration due to the dumpsite (Oguiseju *et al.,* 2015; Ganiyu *et al*., 2016, Ewemoje *et al*., 2017; Akintola and Bodede, 2019a). Composite samples were collected at 0-0.20cm from different sampling points from the dumpsite and also from 500m (upslope) away from the dumpsite, this serve as control.

Sample Preparation and Analysis: The samples were air dried and sieved to less than 2 mm to remove the larger stones and other root materials. Samples were analyzed for particle sizes using hydrometer method (Brown, 2009), soil pH was determined using electrode pH meter in 1-1 water- soil solution while the organic carbon contents of the soils were determined using Walkely and Black (1934). The concentrations of heavy metals (Zn, Cu, Mn, Pb, Ni and Co) were determined using Atomic Absorption Spectrophotometer (AAS) model Accufys 211.

Pot Experiment: Riccinus communis (castor) seeds were obtained from Igangan in Ibarapa Local Government area, Ibadan Oyo State. Before planting, the seeds have undergone treatment to break dormancy by immersing the seeds in warm water for 24 h at 40 °C. Five seeds were directly sown in each pot containing 5 kg of dumpsite soils and control soils.

Riccinus communis plants were grown in a partially shaded location behind the Forestry Technology Department, Federal College of Forestry, Ibadan.
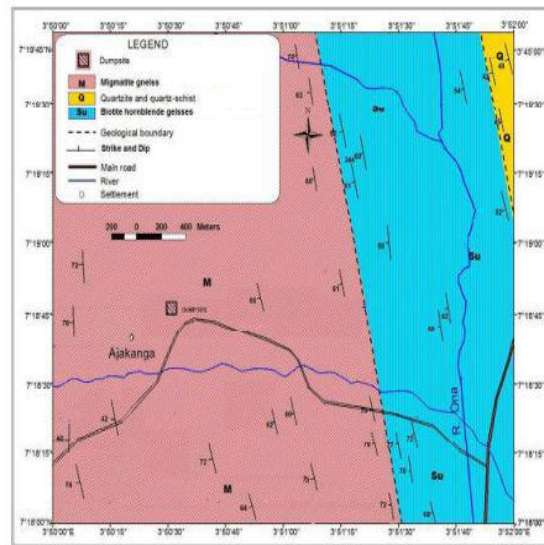

Fig 1. Geological map of the study area after Ogunseiju et al., (2015)

The experiment was replicated five times. All the pots were watered every 2–3 days based on the evaporative demand. Extreme care was taken to prevent water leakage from the pots. After 2 weeks of germination, one seedling was maintained in a pot until the end of the experiment. The plants *Riccinus communis* were harvested after 3 months of growth. The height of plant was measured from the ground level of the soil in the pot to the tip of the stem; leaf area, stem diameter, leaf production and plant biomass were also determined. After thoroughly removing the soil particles, roots and shoots were separated and repetitively cleaned with tap water followed by distilled water, dried for 72 h at 60 °C, and then, the dry weights were measured. The dried roots and shoots were ground with mortar and pestle and stored for further analysis. The soil samples were taking after planting for heavy metal analysis. Both the plant and soil samples were analyzed for heavy metal using Atomic Absorption Spectrophotometer (AAS) model Accufys 211).

Data Analysis: Evaluation indices such as bioconcentration factor (BCF) and transloction factor (TF) were calculated for Mn, Zn. Cu. Pb, Ni and Co to assess the phytoremediation potential of *Riccinus communis.* BCF is described as the ratio of heavy metal concentration in plant shoots to heavy metal concentration in soil as indicated in equation 1; the BCF > 1 is preferable according to Mertens *et al.,*(2005), while TF for heavy metal was calculated

according to the equation 2 given by Stoltz and Greger (2002).

$$BCF = \text{Heavy metal concentration in } \frac{\text{plants}}{\text{soils}} \qquad 1$$

$$TF = \text{Heavy metal concentration in } \frac{\text{Shoots}}{\text{Roots}} \qquad 2$$

Data were analyzed using analysis of variance (ANOVA). Separation of mean were done using Turkey test (P<0.05). All statistical analyses were done using. SPSS (Version 20.0, IBM, USA).

RESULTS AND DISCUSSIONS

Characteristics of soils Prior to Planting: The result of chemical analysis of the soil used for growing media is presented in Table 1. The texture of the soils is sandy loam, thus the soils are suitable for seedling growth and development due to the presence high nutrients, CEC and high water holding capacity (Akintola and Bodede, 2019b). The pH of the control and dumpsite soils was 6.70±0.36 and 6.01±0.25. The pH of the soils is alkalinic in nature. Organic matter content of soils before plantings of dumpsite (T2) and control (T1) were 6.11±0.71% and 4. 67±0.33% respectively. These values were higher compared to similar works conducted by Yashim et al., (2016) Akintola and Bodede, (2019b) and Palanivel *et al.,* (2020) and this bay be attributed to the differences in study location, topographic of the area, geological condition, types of deposited wastes, age of the dumpsites among others. The high organic matter content in the dumpsite soil can be attributed to decomposition and composting processes of the animals waste (which include animal's dung, body parts and blood),plants/vegetable matter and polymer or plastic materials (as the site is also used as a municipal solid waste dump) and also washed away agricultural chemicals (pesticides, insecticides and herbicides) that passed through the dump sit and this confirms why farmers consciously choose to farm on such site(Akintola and Bodede, 2019b). The concentration of heavy metals showed the order of Mn> Zn> Cu> Pb> Ni > Co in the soils. The mean concentration of the studied heavy metals in the dumpsite soil were significantly higher than the control at P<0.05. This indicates that the waste deposited in the site has contributed significantly to the heavy metals contamination of the soil and can be of health risk since crops are planted around the dumpsite.

Growth Performance: The growth parameters determined is presented in Table 2. The Riccinus *communis* plants showed notable growth performance in dumpsite soil (T1) with mean height value of 33.55± 1.01cm while its height in control soil (T2) is 25.33±0.67cm. The respective mean stem diameter of Riccinus *communis* in dumpsite and control soils were 1.76± 0.05 and 0.68cm ± 0.01while the man values of leaf area were 132.66± 2.51 and 100.05 ± 1.09 cm^2 respectively.

Table 1: Mean values of Physiochemical characteristics of soils before planting

Parameters	Treatments	
	Dumpsite soil (T1)	Control soil (T2)
Clay (%)	12 ±0.51[a]	10±0.25[a]
Silt (%)	16±0.89[a]	12±0.41[a]
Sand (%)	73±1.51[a]	78±2.11[a]
Textural type	Sandy loamy	Sandy loamy
pH	6.70±0.36[a]	6.01±0.25[a]
OM (%)	6.11±0.71[a]	4.67±0.33[b]
Mn	220.08±2.51[a]	50.68±0.86[b]
Zn	135.56±1.51[a]	29.01±0.11[b]
Cu	86.88±0.69[a]	8.92±0.09[b]
Pb	48.86±0.27[a]	5.88±0.05[b]
Ni	7.99±0.11[a]	3.01±0.02[b]
Co	6.88±0.08[a]	1.78±0.5101[b]

Different letters between columns are significantly different from each other at P<0.05; OM = organic matter

The mean values of leaf production of the plants in dumpsite and control soils were 28.11± 0.91 and 17.23± 0.34 respectively while the respective mean plant biomass in dumpsite and control soils wee 229.20± 1.99 and 176.12± 1.12g respectively. The significant higher growth parameters noticed in the dumpsite soil when compared to control soil could be attributed to higher amount of organic matter in the soil due to the decomposition of organic wastes and microorganism in the soils. The biomass of the plant varied significantly. The results showed that biomass production for plants gradually increased with treatments (Table 2). It showed that the amounts of heavy metals in the soils did not affect biomass production or induce phytotoxicity symptoms in the plant (Akintola and Bodede, 2019b). *Heavy metal concentration in the growth media before and after planting:* The results of heavy metal concentrations before and after planting were shown in Table3.

Heavy metals concentration (mg/kg) in dumpsite and control soil before planting were Mn (50.68- 220.08); Zn (29.01- 135.56); Cu (8.92- 86.88), Pb (5.88-48.86), Ni (3.01-7.99) and Co (1.78-6.88) while the concentration in soils after planting were Mn (29.89-135.21); Zn (15.11-88.21); Cu (3.89-50.22), pb (3.68-31.56), Ni (1.22-3.56) and Co (0.67-2.68) in Mg/kg. Observed reductions in the heavy metal concentrations in soil after planting can be attributed to the ability of *Riccinus communis to* uptake heavy metals from the soils.

Table 2: Mean values of growth performance of *Riccinus communis.*

Treatment	Plant Height(Cm)	Leaf area (Cm²)	Stem diameter (Cm)	Leaf Production	Plant biomass(g)
T1	33.55± 1.01[a]	132.66± 2.51[a]	1.76± 0.05[a]	28.11± 0.91[a]	229.92± 1.99[a]
T2	25.33±0.67[b]	100.05±1.091[b]	0.68± 0.01[b]	17.23± 0.34[b]	176.2± 1.12[b]

Different letters between rows are significantly different from each other at P<0.05

Table 3: Heavy Metal Concentration in the soil before and after planting

Heavy metals in mg/kg	Dumpsite soils (T1)		Control soils (T2)	
	BP	AP	BP	AP
Mn	220.08	135.21	50.68	29.89
Zn	135.5	88.21	29.01	15.11
Cu	86.88	50.22	8.92	3.89
Pb	48.86	31.56	5.88	3.68
Ni	7.99	3.56	3.01	1.22
Co	6.88	2.68	1.7	0.67

BP and AP denotes before and after planting respectively

Table 4: Heavy Metal Concentration in the *Riccinus communis'* parts

Heavy metals in mg/kg	Dumpsite soils (T1)		Control soils (T2)	
	Shoot	Root	Shoot	Root
Mn	28.22	17.25	7.80	5.65
Zn	25.11	19.89	4.01	3.39
Cu	17.59	13.07	1.36	1.20
Pb	7.60	6.60	1.31	1.27
Ni	1.99	1.89	1.13	1.10
Co	1.36	1.34	0.38	0.37

Heavy Metal Concentration in the Riccinus communis' parts: Heavy metal concentrations in *Riccinus communis'* parts after planting from dumpsite and control soils are presented in Table 4. The results showed that there is variation in heavy metal concentrations in the shoot and roots of the plants. The respective heavy metal concentrations in shoots and roots of the plants from dumpsite soils are: Mn (28.22, 17.25); Zn (25.11, 19.89); Cu(17.59, 13.07); Pb (7.60, 6.60); Ni (1.99, 1.89) and Co (1.36, 1.34) in mg/kg while their respective values from control soils are: Mn (7.80, 5.65); Zn (4.01, 3.39); Cu

(1.36, 1.20); Pb (1.31, 1.27); Ni (1.13, 1.10) and Co (0.38, 037) in mg/kg. According to Huang et al. (2011) *Riccinus communis* has widespread root systems that enable it to penetrate into the soil thus absorbing more contaminants from the soil and transport it into its parts, making it a good remediation potential plants when compared with other plants. In this study, Riccinus *communis* plants accumulated more heavy metals in its shoot than its roots indicating its potential to transfer the heavy metals absorbed through its root from the soil to its different tissue parts. The higher concentration of heavy metals in shoots than roots agreed with similar work conducted by Akintola and Bodede (2019b) on Cederala Odorata plants and Yashim *et al* (2020) on *Riccinus communis* but contrary to the findings of Olivares et al. (2013)

and Palanivel *et al.,* (2020) that suggested that *Riccinus communis* accumulates low concentrations of heavy metals in their aerial parts. The orders of the accumulation of the heavy metals concentration in the plants are Mn> Zn> Cu> Pb> Ni > Co and this may be attributed to the level of availability of this metals in the soil.

Table 5: Values of Bioconcentration (BCF) and Translocation (TF) Factors

Heavy metals in mg/kg	Dumpsite soils (T1)		Control soils (T2)	
	BCF	TF	BCF	TF
Mn	0.34	1.59	0.45	1.38
Zn	0.51	1.26	0.49	1.18
Cu	0.61	1.34	0.52	1.13
Pb	0.45	1.15	0.66	1.03
Ni	1.09	1.05	1.01	1.04
Co	1.11	1.03	1.05	1.03

*Remediation Potential ofRiccinus communis plants:*Bioconcentration (BCF) and translocation (TF) factors are important evaluation indices used to assess the remediation potentials of plant. Mo et al (2008) stated that TF is more of an indicator that reflects that transfer of elements from the roots to the shoots. The results in Table 5 indicated that *Riccinus communis* plants have TF between 1.03-1.59 for all the heavy metals determined from both the dumpsite and control soils. This indicates the ability of the plants to transfer the heavy metals absorbed in the roots from the soil to the shoots. Generally TF< indicate the heavy metals are retained in the root while TF>1 indicated that the roots were able to transfer it to the shoots and they are more concentrated in the shoots (Olivares *et al.,* 2013). In this study, TF>1 agreed with similar work conducted by Yashim et al, (2016) but higher than the TF obtained by Olivares *et al.,* (2013) and Palanivel *et al.,* (2020) for Zn, Cu, Pb, and Ni of the same plants. Bioaccumulation factor (BCF), which is the ratio of heavy metal concentration in plants to soil was used to assess the effectiveness if the studied plants for heavy metal uptake. The BCF values of the heavy metals are between 0.45-0.66 for Mn, Zn, Cu and pb and 1. 01-1.11 for Ni and Co in all the soils used (Table 5). The BCF for Ni and Co were greater than 1 while that of Mn, Zn, Cu and Pb were less than 1. The BCF >1 for Niagreed with the work of Yashim *et al,* (2016) while the values of BCF< 1 for Zn, Cu and Pb agreed with the findings of Palanivel *et al.,* (2020). However, Cluis

(2004) stated that plants with BCF >1 is considered as hyperaccumulators. Thus, this result indicated that *Riccinus communis* plants are hyperaccumulator for Ni and Co. Though, the plants may not be considered as hyperaccumulator for other heavy metals but their enrichment in the plant's tissues is an indication of their bioavalailabilty since they crossed the cellular membrane (Lago-vila *et al.,* 2014). The results of study suggested that *Riccinus communis* plants can accumulate several heavy metals in its roots and transfer them to its shoots, thus decreasing the heavy metal bioavailability and their dispersal.

Conclusions: This study showed that heavy metal concentrations in the dumpsite were higher than the control site which implies that the deposited wastes have significantly contributed to the heavy metals contribution and can be of health risks to surrounding crops and water resource. *Riccinus communis* plants showed significant accumulation of heavy metals in the dumpsite than control soil. Also, concentrations of these heavy metals were more in the shoots of the plants than the roots. Results of this study indicate the accumulation of heavy metals in *Ricinus communis* plants and its potential for effective removal of Cu, Zn, Pb, Ni, Co and Mn from the dumpsite soils.

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