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Uptake of Pb and Cd by Plant Species: A Review

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Abstract:- The use of plants to extract heavy metals from contaminated soil is termed phytoextraction. In recent times, phytoextraction has gained traction as a method for the remediation of spoil soil due to its eco-friendliness and cost-effectiveness. This review study shows how several plant species like Inula viscosa L. artin, Euohorbia dendroides L, Salix Viminalis, Eucalyptus rostrate, Linnum utitatissimum L., Bryopyllum Pinnatum, Cistus salvifolius L, Helichrysium italicum, etc. can be used for the uptake of Lead (Pb) and/or Cadmium (Cd) from contaminated soil. The review demonstrates that the uptake of these heavy metals from soil using selective plant species is effective and efficient.

***Keywords**:- Phytoremediation, Phytoextraction, Plant, Heavy Metals, Lead (Pd) and Cadmium (Cd).*

I. INTRODUCTION

Heavy metal represents metal of relatively high density or high relative atomic weight. Heavy metal includes but not limited to Copper, Zinc, Cadmium, Lead, Nickel and Cobalt. Although these metals are naturally present in the earth crust, their concentration in soil and water mostly ranges from less than 1000ppm to a few ppb. Metalliferous soils are an exception as they naturally harbor extremely high concentrations of certain heavy metals [7; 16]. Anthropogenic activities such as mining, energy production, smelting, electroplating, sludge dumping, melting operations and agriculture have influenced greatly the concentration of heavy metals in areas beyond the critical-concentration [8,17,21]. Several technologies and interventions have been developed for treating metal contaminated soil. These technologies include isolation and containment, pyrometallurgical separation and in-situ stabilization by chemical treatment. Although these technologies are efficient, they are generally costly, labor-intensive and in some cases result in significant secondary damages or disturbance of the soil. In recent times, the use of plant (phytoremediation) in soil remediation has gained massive traction as it is an environmentally friendly and cost-effective approach [10,21].

Phytoremediation refers to the use of plants to remove, transfer, stabilize and/or destroy contaminants in the soil or groundwater [21]. Phytoremediation strategies are phytofiltration, phytostabilization, phytoextraction, phytovolatilisation and phytodegradration [3,4,7]. Among these strategies, phytoextraction has been the commonly used technique [18]. Phytoextraction is the best approach to remove the contamination primarily from the soil and isolate it, without destroying the soil structure and fertility of the plant. According to [15], plant species such as *Salvinia natain, Vallisneira Spiralis* and *Cabomba aquatica* have the potential to uptake heavy metals from spoil land. *Sebera Aciminate, Thlaspic Caerulescene, Arbidoposis thaliana, Typha Latifolia* and *Phragmtic austrials* are also plant species capable of accumulating heavy metals in their tissues [7]. Plants that has a plant to soil ratio (bioaccumulation factor) and shoot to metal ratio (transfer factor) greater than 1 are termed hyperaccumulators [21]. Hyperaccumulators are capable of accumulating at least 1000mg/Kg of Cd, 1000mg/Kg of As, Cu, Pb, Ni, Co, Se, Cr or 10000mg/Kg of Mn or Zn [14,18].

[1] study showed a high Lead contamination of soils in most part of Tema, Ghana and [2] study also found high levels of Cd in several soils in Ghana. Remediating these Pb and Cd contaminated soils by plant will require the use of selective plant species.

The current review is about literature survey on the phytoextraction of Lead (Pb) and/or Cadmium (Cd) using selective plant species.

II. REV IEW ON PHYTOEXTRACTION

- *Linnum utitatissimum L.*

Seeds of *Linnum utitatissimum L.* were sterilized and germinated in a pot with a diameter of 28cm and depth of 30cm filled with clay soil. The study employed four groups of identical pots. One group as the control, one with 10, 20, and 40mg/kg of $CdCl_2$ and the other group with $Pb_2(CH_3OO)_2$ of 150, 500 and 700mg/kg respectively. Fertilizers were applied carefully to the various pot. The concentration of Pb and Cd in the soil samples was analyzed using AAS.

Cd concentration in the plant roots was higher than those in the aboveground parts of the plant with 77.4% in the soil sample treated with 40mg/kg soil Cd. The Cd concentrations in the parts of the plant were in the order of root > shoot > capsule > seed. The highest Pb concentration in the plant was 55% in the soil sample treated with 700mg/kg soil Pb. The Pb concentration was in the order of capsule > shoot > root > seed. Bioaccumulation factor (BF) and transfer factor (TF) were greater than 1 for Pb but less than 1 for Cd. The TF for Pb treatment was greater than 1 for the shoot and capsule but less than 1 for the seed and in the order of capsule > shoot > seed. The uptake potential of the heavy metals from the soil was 68.6% for Pb and 49% for Cd. The highest uptake of Cd was recorded in the root while that of Pb was recorded in the capsule. The study showed that

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Linnum utitatissimum L. is a hyperaccumulator of Pb and an excluder for Cd. [12].

- *Salix Viminalis*

The phytoextraction potential of *Salix Viminalis* on Cd and Pb was determined on two different sites, one calcareous and the other acidic. The study on the first site lasted for 5years while the latter lasted for 2years.

In the first year, the uptake of heavy metals by the plant species was negligible but significant in the following year(s). The uptake of the heavy metals under study increased upon the addition of chelate agent Fe. The metal uptake at the acidic soil was twice higher than at the calcareous soil when uptake after two years was compared. The total uptake was 170g/ha for Cd from the calcareous soil for the five-year study period and 47g/ha of Cd at the acidic soil after the two-year study period. *Salix* Viminalis performed better on the acidic soil as compared to the calcareous soil mainly because of the higher biomass production and higher metal concentration in the shoot. The leaves accumulated a higher amount of Cd than the stem. The concentration of the heavy metals decreased in the shoot over time. The study concluded that *Salix Viminalis* could have the potential for stabilization of contaminated soil. [11].

- *Ricenus communic cv. Guarary*

Pd, Cd and other heavy metals were the control of this experiment. The plant species were grown in pots filled with Hoagland and Amon's nutrients. In this experiment, six different Pb concentration (0, 6, 12, 24, 48 and 96mg/kg) in the form $Pb(No_3)_2$ and Cd concentration (0, 1, 2, 4, 8 and 16mg/kg) in the form of $Cd(No_3)_2$ were added to soil samples in two separate pots for 3days: the first pot was for Cd and the other for Pb. The plant was harvested after 30days and prepared for analysis. The heavy metal concentrations were determined using flame-AAS. TF, BF and Effective Concentration (EC25 AND EC50) for growth in response to Cd were calculated. EC25 and EC50 exposures are the values at which the dry weight/matter reduces by 25% and 50% relative to the highest value for the dry matter (100%).

Pb had no effect on the dry matter of the plant but an increase in the concentration of Cd in the hydrophone system led to a reduction of root and shoot dry matter. At the lowest concentration of Cd (1mg/kg), there was a reduction of 44% and 55% in the root and shoot dry matter respectively. For the highest Cd concentration, reduction in the dry matter of the root and shoot was 97% in both root and shoot. EC25 and EC50 values were 0.5 and 1.1mg/L for the root, 0.4 and 0.9mg/L for the shoot respectively.

For this study, TF was less than 1 for Cd and Pb while BF was greater than 1 for Cd and less than 1 for Pb except for the concentration of 24 mg/L of Pb. The Pb and Cd concentrations found in the shoots were both smaller than 1000mg/kg. Cd was more toxic to the plant while the plant showed a significant tolerance for Pb. *Ricenus communic cv. Guarary* is more efficient for the phytoextraction of Pb. [5].

- *Helichrysium italicum, Arundo dinax L., Cistus salvifolius L., Poa annua L., Holosclaenus australis L. Rchb, Inula viscosa L. artin and Euohorbia dendroides L.*

The phytoextraction potential of the above plant species on an abandoned mine was studied. Inductively Coupled Plasma – Optical Emission Spectroscopy (ICP-OES) was used in determining Cd concentration while Pb concentration was determined using Flame-ASS equipped with background correction. The mean concentration of Cd and Pd was 1800mg/kg and 56mg/kg in the tailings. In the sediments, the mean Pb and Cd concentrations were 2900mg/kg and 100mg/kg and 200mg/kg and 80mg/kg in the pasture soil.

The highest metal accumulation in the lower parts (root and rhizome) was seen in *Poa annua L.* and *Holosclaenus australis L. Rchb* while that of the upper parts (leaves and stems) were seen in the remaining species. The Pb concentrations accumulated by the plants ranged from 3 – 1300mg/kg with the highest recorded in the root of *Euohorbia dendroides L.* In the aerial parts, the highest Pb concentration was 950mg/kg found in *Helichrysium italicum. Inula viscosa L. artin and Euohorbia dendroides L* showed high Pb content in their leaves (700 and 650mg/kg respectively). Cd concentration in the plants ranged from 0.5 to 170 mg/kg with the highest concentration recorded in the root *of Poa annua L.* The highest Cd concentration in the aerial parts was 44mg/kg found in *Inula viscosa L. artin.* The species *Inula viscosa L. artin, Euohorbia dendroides L.* and *Poa annua L* showed relatively high metal uptake in the aboveground biomass with mean averages of 420, 240 and 80mg/kg of Pb and 28, 7 and 19mg/kg of Cd respectively. *Arundo dinax L* also demonstrated a significant potential for the phytoextraction of Cd and Pb. *Cistus salvifolius L* and *Helichrysium italicum* demonstrated behaviors more suitable for phytostabilization. [3].

- *Ipomoea aquatic and Spinacia oleracea*

In this study, synthetic soil was induced with 66ppm of $Pb(No_3)_2$ and 30ppm of $Cd(No_3)_2$ that resulted in Cd and Pd concentrations of 14.4mg/kg and 36mg/kg in the soil.

Seeds of the plants were planted in an unpolluted soil and transplanted in the synthetic coil after 2months of growth. After 35days following the transplant, the concentration of the metals was analyzed using AAS. The phytoextraction potential of the plants was expressed as percentages. TF for Pb and Cd was estimated.

The growth of the plants was inversely proportional to the concentration of the heavy metals. There were shorter lengths of roots of the plants exposed to the heavy metals compared to those harvested from the unpolluted soil. The shorter length of the roots could be attributed to the higher concentration of Cd. For the Pb concentration (66ppm), TF was 0.49 for *Ipomoea aquatic* and 0.17 for *Spinacia oleracea.* For the Cd concentration (30ppm), TF was 0.48 for *Ipomoea aquatic* and 0.38 for *Spinacia oleracea.* The accumulation of Cd was greater than Pb for both species. *Ipomoea aquatic* had the highest efficiency for the removal of Pb and Cd with 27.79% of Pb and 29% of Cd. The potential for phytoextraction was higher *in Ipomoea aquatic* than *Spinacia oleracea.* [20].

- *Acacia saligna, Eucalyptus rostrate and Conocarpus erectu*

This study was to determine the ability of the above species to uptake Pb and Cd in plastic pots containing soil mixed with fine powders of $CdCl_2$ and $PdCl_2$. The soil in the plastic pots had Pb levels of 00, 250, 500 and 1000mg/kg and Cd levels of 0, 250, 500 and 1000mg/kg soil. Three months old seedlings of the species were transplanted in the plastic pots with sand, peat moss and a pH of 7.2. There was the addition of water-soluble fertilizers. After harvest, the concentration of Pb and Cd in the plant tissues were analyzed using ICP-AES (Inductively Coupled Plasma – Atomic Emission Spectroscopy). Peroxidase and Catalase activities were also studied.

Catalase activity increased at Pb1 and Pb2 but decreased at Pb3 for all plant species while it increased at Cd1 and Cd2 for only *Acacia saligna* and *Eucalyptus rostrate* but decreased at Cd3 for all species. Peroxidase activity increased in Pb1 and Pb2 for all species and also increased in Cd1 and Cd2 but decreased in Cd3 for all species. The highest level of Cd treatment (1000mg/kg) caused a reduction of the dry shoot weight by 39%, 45.8% and 49.3% while the highest Pb treatment resulted in a decrease of the shoot dry weight by 25.8%, 27.4% and 35.8% in *Acacia saligna, Eucalyptus rostrate* and *Conocarpus erectu* respectively. The lowest Pb treatment resulted in an increase in the shoot dry weight by 15.9%, 13.6% and 8.7% in *Acacia saligna, Eucalyptus rostrate* and *Conocarpus erectu* respectively. The plants showed a low tolerance for Cd concentrations. Unlike *Conocarpus erectu*, the Pb and Cd accumulated in *Acacia saligna and Eucalyptus rostrate* were higher in the roots than in the shoots. The highest uptake of Pb and Cd content was by *Acacia saligna* (625 and 62 mg/kg in the root and 258 ad 32mg/kg in the shoot). The Pb and Cd content were 552 and 52mg/kg in the root and 316 and 43mg/kg in the shoot of *Eucalyptus rostrate*. For *Conocarpus erectu,* the Pb and Cd content was 165 and 35mg/kg in the root and 285 and 56mg/kg in the shoot respectively. TF for both Pb and Cd was less than 1 for *Acacia saligna and Eucalyptus rostrate* but greater than 1 for *Conocarpus erectu.* Although large amounts of metal content were accumulated in the roots, only lower levers were translocated into the shoot in the case of *Acacia saligna and Eucalyptus rostrate*. The highest metal uptake was by *Acacia saligna*. Cd had a high inhibition effect than Pb on the weight of the roots and shoots of the plant species. The dry weight of shoots and roots reduces for all plant species as the concentration of the heavy metals increases. There was a significant tolerance to heavy metal concentrations by *Acacia saligna* than the other plant species. *Conocarpus erectu* showed the least tolerance to increasing concentration of the heavy metals. All three plant species demonstrated significant potential for the uptake of heavy metals. [19].

- *Delonox regra, Leucaena leucocephala and Thespesra populneoicles*

The removal of Cd and Pb by the above plant species were studied using a pot experiment. The seedlings were grown on the soil induced with Lead Acetate and Cadmium Chloride of concentrations 25, 50, 75, 100 and 125ppm. The experiment employed completely randomized design (C.R.D) and the data were analyzed using analysis of variance and Duncan's multiple ranges of tests. Tolerance index (T.I), Diclofenac (DFC) and phytotoxicity were estimated as percentages.

For all three species, a reduction in growth was observed. The aerial germination was not significantly affected by the induced Pb and Cd toxicity. *Thespesra populneoicles* depicted a 50% reduction in germination at 1000ppm for Cd toxicity while *Delonox regra* and *Leucaena leucocephala* showed a reduction lesser than 50% at the same Cd toxicity. *Leucaena leucocephala* germination exceeded 90% in the Lead Acetate and 70 – 80% in Cadmium Chloride. There were higher percentages of DFC in *Delonox regra* than the remaining plant species, thus *Delonox regra* seeds are more susceptible to these heavy metals. The high levels of Pb and Cd resulted in a decrease of the root length of all the investigated plant species with the highest reduction observed in the 125ppm of Cd and Pb. The average T.I of Pb and Cd were 69.1 and 53.38 for *Delonox regra, 53.99* and *16.6* for *Leucaena leucocephala* and 59.32 and 38.89 for *Thespesra populneoicles* respectively. In general, Cd exhibited a toxic potential to the plants than Pb. The higher the concentration of the metals, the slower the germination of the seedlings. The growth of *Leucaena leucocephala* was least affected by Cd and Pd. Tolerance for Cd and Pb was highest in *Delonox regra* but moderate in the remaining plant species. *Delonox regra* demonstrated a higher phytoextraction potential than the other investigated plant species. [13].

- *Panicum virdatum L.*

The efficiency of *Panicum virdatum L.* to uptake Cd and Pd in 3 groups of 5 replica pots with five different concentrations of Pb (195.4, 400, 700, 1000 and 1204.6μg/g) and Cd (9.45, 30, 60, 90 and 110. 46μg/g) and five different pH (3, 4.1, 5.8, 7.5 and 8.6) was studied. The seeds were germinated, transferred to a plastic container with quartz sand and then transplanted in the pots. The pots were all supplied with adequate nutrient solution and water. 50mg/kg solution of $CdCl_2$ and $Pb(No_3)_2$ were added to each pot every 2days while adjusting the pH. Superoxide dismutase (SOD) and Peroxidase (POD) activities were also determined.

SOD and POD and Malondialdehyde (MDA) activities were affected. The interaction of Cd and Pb in the soil had an antagonistic effect on the BF of Cd while the interaction of pH with Cd or Pb showed a synergistic effect on the BF of Cd. The Cd and Pb concentrations were higher in the root than in the shoot. The accumulated Cd concentrations in the root and shoot range from 33.86 – 487.61μg/g and 6.63 – 59.43μg/g respectively. Pb concentration accumulated in the root and shoot ranged from 64.87 – 2205.52μg/g and 10.76 – 104.27μg/g respectively. BF for Cd was greater than 1 but less than 1 for Pb while TF for both Cd and Pb was less than 1. The study concluded that *Panicum virdatum L.* could grow in the soil with a Cd concentration of 48.68µg/g, Pb concentration of 56.75µg/g and a p.H of 5.34. *Panicum virdatum L.* was more efficient in the removal of Cd than Pb. [9].

- *Bryopyllum Pinnatum*

In this study, the species was planted on a polluted soil and nurtured for 20weeks. The plant and soil were collected and analyzed every four weeks. The metal concentrations were analyzed using the wet digestion method. The total concentration of Cd and Pb were determined using Atomic Absorption Spectrometer (AAS) equipped with attractive background correction. Cd concentration extracted by the plant species was 3.12 ± 1.03 mg/kg while Pb was 399.90 ± 4.32mg/kg. The uptake of heavy metals increases as the period of exposure to the heavy metals increases except for the fifth month. The bioaccumulation of the heavy metals was in the order of Pb > Cd. Therefore, *Bryopyllum Pinnatum* has higher phytoextraction potential for Pb than Cd in this very experiment. [6].

Table 1 shows the plants species and their respective TF and BF on Pb and Cd.

Plant Species	*TF*		*BF*	
	Pb	***Cd***	***Pd***	***Cd***
Linnum utitatissimum L	>1	<1	>1	<1
Ricenus communic cv Guarary	<1	<1	<1	>1
Ipomoea aquatic	<1	<1	-	-
Spinacia oleracea	<1	<1	-	-
Acacia saligna	<1	<1	-	-
Eucalyptus rostrate	<1	<1	-	-
Conocarpus erectu	>1	>1	-	-
Panicum virdatum L	<1	<1	<1	>1

Table 1:- TF and BF of plant species

III. CONCLUSION

The uptake of Pb and/or Cd potential of *Delonox regra, Leucaena leucocephala, Thespesra populneoicles, Acacia saligna, Eucalyptus rostrate, Conocarpus erectu, Ipomoea aquatic, Spinacia oleracea, Bryopyllum Pinnatum, Panicum virdatum L., Helichrysium italicum, Arundo dinax L., Cistus salvifolius L., Poa annua L., Holosclaenus australis L. Rchb, Inula viscosa L. artin, Euohorbia dendroides L., Ricenus communic cv. Guarary, Salix Viminalis,* and *Linnum utitatissimum L.* have been effectively discussed. Most of these species demonstrated significant uptake of Pb and/or Cd, signifying their effectiveness for the phytoremediation of these heavy metals. *Linnum utitatissimum L* was a hyperaccumulator for Pb and an excluder for Cd. *Cistus salvifolius L., Salix Viminalis* and *Helichrysium italicum* showed behaviors suitable for phytostabilization. In most scenarios, increasing concentration of heavy metals showed a toxic effect on the growth of the plant species. High concentrations of Cd showed an inhibiting effect on *Ricenus communic cv Guarary* and *Conocarpus erectu.*

The majority of the studies conducted were in the laboratory settings (pot experiment), field experiments will be required to understand the phytoextraction abilities of the plant species fully. Phytoremediation has proven effective in many studies, and hence, it should be given more attention, especially in Ghana.

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