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Effective Use of Green Plants in Remediation of Contaminated Environment with Heavy Metals and Persistent Organic Pollutants

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Abstract- Phytoremediation which is a green technology method for heavy metals, radionuclide and persistent organic pollutants remediation using plants to degrade, stabilize, and/or remove contaminants has got many attention nowadays. It is an environmental friendly, economical, cheap and low maintenance method. There are many species of plant having the ability to degrade heavy metals, radionuclide and other persistent organic pollutants in their growth medium. This paper reviewed on the effective use of green plants in remediation of contaminated environment with heavy metals and persistent organic pollutants. The paper also reported more than 15 plants species of different families for effective remediation of contaminated environment.

Keywords: Accumulation, contamination, concentration, environment, green plants.

I. INTRODUCTION

Due to urbanization and industrialization, environment (soil, water and air) have become increasingly polluted by heavy metals and organic pollutants, which threaten ecosystems, surface and ground waters, food safety and human health [1,2]. Various remediation techniques, based on either mobilization or immobilization processes, have been developed to solve these challenges. Of those methods, phytoremediation is increasingly being recognized as a promising technology that can be used to remediate various contaminations in soil [3]. Phytoremediation is a generic term for the group of technologies that use plants for remediating soils, sludges, sediments and water contaminated with organic and inorganic contaminants [4]. This techniques, also called green remediation, botano-remediation, agroremediation, or vegetative remediation is considered a publicly appealing (green) remediation technology that uses vegetation and associated microbiota, soil amendments and agronomic techniques to remove, contain, or render the heavy metals harmless in the soil [5,6,7,8]. It has been increasingly received attentions over the recent decades, as an emerging and eco-friendly approach that utilizes the natural properties of plants to remediate contaminated soils [1,9]. It is a green technology and when properly implemented is both environmentally friendly and aesthetically pleasing to the public [10]. As a green technology, it is applicable for different kinds of organic and inorganic pollutants and provides aesthetic benefits to the environment by using trees and creating green areas, which is socially and psychologically beneficial for all [11,12]. This green technology is suitable for large areas in which other approaches would be expensive and ineffective [13,14].

II. HYPER ACCUMULATORS

Several plants species are known to tolerate high concentration of toxic metals. Tolerant species are best described as excluders, where metal uptake and translocation to different tissue parts are limited [15]. The phytoremediation of heavy metals involve many physiological, biochemical and molecular activities. The plant species have capabilities to uptake and accumulate high levels of metallic organic compounds without any toxic impacts, such as reed plants (Phragmites australis), Indian mustard (*Brassica juncea* L.), willow (Salix species), poplar tree (Populus deltoides), Indian grass (*Sorghastrum nutans*), sunflower (Helianthus annuus L.), water hyacinth (*Eichhornia crassipes*), channel grass (Vallisneria spiralis), alfalfa (Medicago sativa), brassica (Brassica napus), kenaf (*Hibiscus cannabinus* L.), tall fescue (Festuca arundinacea Schreb), bermudagrass (Cynodon dactylon), and barley (Hordeum vulgare L.). According to [16,17] hyperaccumulator plants have mainly been reported from family *Brassicaceae, Cunouniaceae, Caryophyllaceae, Asteraceae, Euphorbiaceae, Cyperaceae, Fabaceae, Lamiaceae, Violaceae, Poaceae*, among others.

The bioconcentration factor (BCF) and translocation factor (TF) are usually used to evaluate plant ability to tolerate and accumulate heavy metals. The BCF is the ratio of metal concentration in the plant tissue to the soil and TF is the ratio of metal concentration in plant shoots to the roots [18]. These plant species have attained heavy metal tolerance characteristics that modified them to survive in highly heavy metal polluted ecosystems and they show high strength to accumulate heavily metallic ions, such as nickel, zinc, copper, chromium, and even radionuclides [19].

II.I *ACACIA NILOTICA*

Baunthiyal and Sharma [20] investigated the potential of eight tree species of semi-arid region including *Acacia tortilis, Acacia nilotica, Acacia senegal, Prosopis cineraria, Prosopis juliflora, Cassia fistula, Azadirachta indica and Albizzia lebbeck* for hyperaccumulation of Fluoride. Based on the accumulation pattern, three plants *A. tortilis, P. juliflora* and *C. fistula* were selected for Fluoride uptake and deposition in different organs and their subcellular fractions.
The work of [21] designed an experiment for uranium uptake from sandy soil treated with different concentration of uranium using *Acacia albida* and *Acacia nilotica*. The results showed a difference in the ability of the *Acacia* seedlings tested to absorb different concentrations of uranium through their roots. *A. nilotica* registered the highest levels of absorption and accumulation of uranium in dry weight of roots in different concentrations (202, 339, 1175, and 1477 µg.g-1) respectively of the concentrations (50, 100, 200, and 500 mgkg-1). Compared to the root of *A. albida*, the absorption of uranium was (60, 54, 133, and 526 µg.g-1) in the concentrations of the same samples. The ability of *A. nilotica* is better than that of *A. albida* to uptake uranium from the soil, where 80-90% of the uranium is absorbed by the seedlings, compared to 44-85% in *A. albida*.

II.II *ADANSONIA DIGITATA AND AZADIRACHTA INDICA*

Waziri *et al.,* [22] examine the potentials of Neem (*Azadirachta indica*) and Baobab (*Adansonia digitata*) for phytoremediation of some heavy metals in the industrially contaminated soils of Challawa in Kano, Nigeria. The plants were grown under hydroponic greenhouse conditions for thirteen weeks and levels of metals in plants, soil and effluent water were determined using Atomic Absorption Spectrophotometer. The mean concentrations of the metals ranged from 4.33±0.02mg/kg Pb to 453.15 ±42.32mg/kg Fe and 2.6 ± 0.01 mg/kg to 114.6 ± 23.24 mg/kg for plants grown in the contaminated and control soils respectively.

II.III *AXONOPUS COMPRESSUS AND BRASSICA JUNCEA*

The study of Ighovie and Ikechukwu [23] assessed the effectiveness of carpet grass (*A. compressus*) in the phytoremediation management of oil impacted soil in Ubeji (Ub) and Alesa Eleme (AE) communities of Niger Delta region of Nigeria. The findings of the research showed that the growth of *Axonopus* sp. in the crude oil-impacted soils of Ub and AE has reduced the acidity of hydrocarbon content in soils (4.46 - 6.87 pH in Ub and 4.66 - 6.86 pH in AE) from the first day to the 90th days of experiment, and thereafter there was stabilization at the 4th month.

Ukoh *et al.*, [24] reported that *A. compresus* and *Panicum maximum* growing on Zinc polluted soils show a slight reduction in growth due to changes in their physiological and biochemical activities. However, *A. compresus* and *P. maximum* both significantly reduced greater percentage of Zn in the polluted soil. The study suggests *A. compressus* to have greater impacts on Zn polluted soil than *P. maximum*. *A. compressus* is a better removal of Pb than *P. Maximum*. However, both *A. compresus* and *P. maximum* have the tenacity and phytoremediation capacity to remediate Zn in soil effectively.

Indian mustard (*Brassica juncea*) has been shown to be effective at accumulating high tissue concentrations of lead when grown in contaminated soil with the addition of a chelating agent, such as EDTA [25]. The study of [26] reported the uptake of Cd, Pb and Zn at various concentrations, i.e. 0, 5, 10, 20 and 50 µg ml-1in Steinberg's solution over a period of 21 days using *Brassica juncea*. The result revealed the high potential of *B. Juncea* in remediating of Cd, Pb and Zn from aquatic environment with up to a maximum concentration of 50 µg ml-1. According to [27] the ability of *brassicas* to bioaccumulate heavy metals can be used to reduce the level of contaminants in the soil (phytoremediation), and thus to clean up and prepare soils for cultivation.

Singh and Fulekar [28] observed the depletion of heavy metals at the intervals of 0, 1, 3, 7, 14 and 21 days and studied metal uptake in the roots/shoots of *B. juncea*. The result showed the percentage removal of Cd, Pb and Zn to be 88.9%, 80% and 89.8%, respectively at the higher exposure concentration (50 ppm). Similarly *B. juncea* has also been used for phytoremediation of heavy metals (Cd, Pb and Zn) at varying concentrations, viz., 0, 5, 10, 20 and 50 mg/kg from mycorrhizal soil in pot culture technique and uptake was studied in the roots/shoots after harvesting the plants. Reference [29] reported that Indian mustard (*Brassica juncea* L.) is the plant for the production of high biomass and rapid growth, and it seems that the appropriate species for phytoextraction because it can compensate for the low accumulation of cadmium with a much higher biomass yield. *B. juncea* has the ability to reduce contamination of the food chain through hyper-accumulation since it has high amounts of thiocyanates which make them unpalatable to animals [30,31].

II.IV *CASSIA TORA* AND *CERATOPHYLLUM DEMERSUM*

Ghosh and Singh [32] investigated and compared five weed species (*Ipomoea carnea*, *Dhatura innoxia*, *Phragmytes* *karka Cassia tora* and *Lantana camara*), with two accumulator plants *(Brassica juncea* and *Brassica campestris*), in a pot study to assess Cr uptake in the range of 5 to 200 mg/kg soil. The results indicated that *P. karka* showed much greater tolerance to metals than other plants, though the uptake was low. Nayana and Malode [33] investigated the capacity of *Cassia tora* (Caesalpinioideae) to remove contaminant in waste soil polluted by various heavy metals. Heavy metal analysis of initial waste soil, contained Cu (0.748 mg/g), Zn (5.032 mg/g), Cr (0.220 mg/g), Ni (0.492 mg/g), Fe (18.90 mg/g), Mn (6.081 mg/g), Co (-0.157 mg/g) these all metal concentrations lower down except Zn, Cr and Fe after the *Cassia tora* grown in this soil during 2 month period and Cu (0.581 mg/g), Zn (0.184 mg/g), Cr (0.465 mg/g), Ni (0.1005 mg/g), Fe (22.09mg/g), Mn (4.811 mg/g), Co (-0.022 mg/g). The result revealed that *Cassia tora* have a capacity to accumulate certain metals from waste soil and analyzed the amount of toxicity and various nutrients of soil.

Badamasi *et al.,* [34] and [35] reported that *Cassia multijuga* was found to be highly capable of absorbing and accumulating Pb. Reference [32,34,36] also reported that *Cassia tora* (L) accumulated high concentrations of heavy metals including Pb in their leaves and root, which reduced their negative effect on the ecosystem. Badamasi *et al.,* [34] aimed to study the potentials of *C. tora* (L) in the phytoremediation of Pb using hydroponic culture protocol. Based on this findings, *C. tora* (L) could be used in phytoremediation of Pb contaminated environment at low level concentrations. Ramanlal *et al.,* [37] checked the accumulation of three heavy metals including Cd, Pb and Zn in two native plant species *Amaranthus spinosus* and *C. tora* showed high affinity of plants towards uptake of Zn and Pb. Of the two plants species, *C. tora* showed high accumulation of Zn and Pb with a translocation factor of >1which makes it a potent candidate for incorporating into phytoremediation studies.

Suryani *et al.,* [38] determined the efficiency of *Ceratophyllum demersum* L. in remediation of chrome in tannery wastewater. In the study, 84 strands of *C. demersum* compound leaves of 30g weight were used. The results showed that the highest efficiency was at the concentration of 7.74 mg/L with 1.7% chromium, 17.3% water turbidity, and 46% BOD. Also, the highest efficiency of total chlorophyll level was 3.88 mg/L, reached at the concentration of 17.00 mg/L. The result recommended that, *C. demersum* is good to use as a phytoremediator of tannery wastewater at the concentration of 7.74 mg/L.

II.V *JATROPHA CURCAS* AND *EICHHORNIA CRASSIPES*

Awalla [39] discovered that *J. curcas* plants through their roots, stems and leaves metabolism, morphology and mechanisms can reduce the concentration of heavy metals like Zn, Pb, Cr, Cd, and Cu effectively from any medium containing 100% sewage sludge. However, *J. curcas* plant is suitable as a phytoremediator of heavy metals in soils. Waziri *et al.,* [22] examine the potentials of Jatropha (*Jatropha curcas*) for phytoremediation of some heavy metals in the industrially contaminated soils of Challawa in Kano, Nigeria. The plants were grown under hydroponic greenhouse conditions for thirteen weeks and levels of metals in plants, soil and effluent water were determined using Atomic Absorption Spectrophotometer. The mean concentrations of the metals ranged from 4.33±0.02mg/kg Pb to 453.15 ±42.32mg/kg Fe and 2.6 ± 0.01 mg/kg to 114.6 ± 23.24 mg/kg for plants grown in the contaminated and control soils respectively. A total of one hundred and eighty (180) samples comprising of 80 (soils), 20 (effluents), and 80 (plant parts) of Jatropha were analyzed [40]. The results of the analysis showed that these plants can be used for the phytoextraction of the metals from contaminated soils.

The experiment of Ramadan *et al.,* [41] was conducted to determine the extent of *J. curcas* efficiency to the remediation of zinc and copper contaminated soils amended with sewage sludge. The results had significantly proved that *J. curcas* had great ability to uptake and subsequently translocate Zn and Cu in their parts. It was also believed that *J. curcas* varied in their tolerance to heavy metals toxicity. Furthermore, their efficiency of extracting of Zn and Cu from soils is dependent not only on their concentration in the sewage sludge, but also on the properties of the soil.

Okechukwu and Madagwa [42] pointed out that, *E. crassipes* has proved its promising technique for the removal / bioaccumulation of contaminants from crude oil polluted water. Its rooted nature has favored increased rhizosphere activity, thereby enhancing nutrient and metal uptake. The study of Tan *et al.,* [43] indicated that *Eichhornia crassipes* has a potential to decolorize different synthetic dyes. Based on the results obtained, the percentage of color removal of methyl blue (MB) is 98.42%, while methyl orange (MO) is 66.80%. The pH of the MB and MO dye aqueous solutions fluctuated throughout the experiment. Which was due to the free diffusion of the carbon dioxide with the atmosphere and the uptake of nutrients by the plant. The relative growth rate of *E. crassipes* in MB dye aqueous solution and the MO dye aqueous solution was 0.02 days-1 and 0.03 day–1 respectively.

II.VI *HELIANTHUS ANNUUS* AND *HIBISCUS CANNABINUS*

Sewalem *et al.,* [44] conducted research and showed that high amount of the total up taken Cd (88.84%) was accumulated in roots with low amount (11.16%) translocated to shoots of sunflower seedlings. On the other side, high amount of the total up taken Pb (71.39) was translocated to shoots with low amount (28.61) stayed in roots of sunflower seedlings. Similar trends of Cd and Pb allocation between roots and shoots at the yield stage were recorded. Martins *et al.*, [45] demonstrated the potential of the phytoremediation technique using sunflower for the treatment of soil multi-contaminated by heavy metals and hydrocarbon's petroleum. The analysis was performed using three different sunflower cultivars (H2, P and M). The three tested sunflower cultivars presented the same growth and biomass under multi-contaminated and noncontaminated soils. All of them were also capable of removing benzo(a)pyrene, TPH, and metals from multi-contaminated soil. The amount of contaminants removed from soil varied according to the sunflower cultivar used. Sunflower H2, P and M can hyperaccumulate Cu, Pb, Ni and V from multicontaminated soil. Reference [29] reported that Sunflower (*Helianthus annuus* L.) is the plant for the production of high biomass and rapid growth, and it seems that the appropriate species for phytoextraction because it can compensate for the low accumulation of cadmium with a much higher biomass yield.

Mun *et al.,* [46] investigated the potential of *Hibiscus cannabinus* L. for phytoremediation of lead (Pb) on sand tailings. The result showed that Pb was found in the root, stem, and seed capsule of *H. cannabinus* but not in the leaf. *H. cannabinus* was also found to have higher biomass and subsequently higher bioaccumulation capacity after fertilizer application, indicating its suitability for phytoremediation of Pb-contaminated site. Also, the ability of *H. cannabinus* to tolerate Pb and avoid phytotoxicity could be attributed to the immobilization of Pb in the roots and hence the restriction of upward movement.

The experiment of Ramadan *et al.*, [41] was conducted to determine the extent of *J. curcas* and *H. cannabinus* efficiency to the remediation of zinc and copper contaminated soils amended with sewage sludge. The results had significantly proved that *J. curcas* and *H. cannabinus* had great ability to uptake and subsequently translocate Zn and Cu in their parts. It was also believed that *J. curcas* and *H. cannabinus* varied in their tolerance to heavy metals toxicity. Furthermore, their efficiency of extracting of Zn and Cu from soils is dependent not only on their concentration in the sewage sludge, but also on the properties of the soil.

II.VII *LEMNA MINOR* AND *NYMPHAEA LOTUS (WATER LILY)*

Bokhari *et al.*, [47] evaluated the phytoremediation potential of *L. minor* for cadmium (Cd), copper (Cu), lead (Pb), and nickel (Ni) from two different types of effluent for a period of 31 days. The effluents were analyzed for physical, chemical and microbiological parameters and results indicated that municipal effluent was highly contaminated in terms of nutrient and organic load than sewage mixed industrial effluent. Daud *et al.*, [48] reported the removal efficiency of *L. minor*, for all the metals (Cu, Fe, Ni, Pb, Zn) analyzed from landfill leachate to be more than 70% with the maximum value for copper 91%. The values of chemical oxygen demand (COD) and biological oxygen demand (BOD) was reduced by 39% and 47%, respectively. Also, physiochemical parameters like pH, total suspended solids, (TSS) and total dissolved solids (TDS) were reduced by 13%, 33%, and 41%, respectively.

Heavy metal accumulation studies in *Nymphaea lotus* (Water lily) were carried out from eight different locations along the stream using the Atomic Absorption spectrophotometric technique [49]. The levels obtained for the metals were in the range of 79.80- 130.20mg/100g for Zinc, 50.19- 69.90mg/100g for Lead, 53.60- 58.20mg/100g for Iron and 7.21- 8.9mg/100g for Cadmium. The results showed that the plant has high tendency to selectively bioaccumulate Zinc and Lead thus suggesting that it could be used to monitor Zinc and Lead levels in the stream. However, the study indicates that the plant has high potential to selectively uptake lead and zinc faster than cadmium and iron in the stream.

II.VIII *TERMINALIA SUPERBA* AND *THLASPI CAERULESCENS AND T. DOMINGENSIS*

The effect of different levels of diesel oil contamination (25 ml (T1), 50 ml (T2), 75 ml (T3) and 100 ml (T4) of diesel oil per kg of soil) on seedlings of *Khaya senegalensis* and *Terminalia superba* were determined by [50]. The tolerance of diesel oil contamination by the two plant species indicates their potential for phytoextraction of heavy metals from hydrocarbon polluted areas in the tropics and further studies will be required to identify their tolerance limits. The work of [51] studied the utility of *T. superba* and other plant species in Ghana for remediating mine degraded soils. The roots, stalks and leaves of the *T. Superba* were analysed for heavy metal accumulation. It was found that *T. superba* (Ofram) have accumulated significant concentrations of the heavy metals and are highly suitable for cleaning copper, cadmium, lead, manganese and iron contaminated sites.

Thlaspi caerulescens reported for Cd hyperaccumulation in the early 1990s. *T. caerulescens* showed much greater tolerance to Cd, with toxicity symptoms appearing at the 200 µM concentration [16]. Some research results confirmed that, *T. caerulescens* as a hyperaccumulating plant for the remediation of Cd pollution. The findings of [52] demonstrated the capacity of *T. domingensis* in the effluent drainage for the removal of heavy metal pollutants. The plant species could be used for phytoremediation of industrial effluent contaminating ecosystems.

III. OTHER PLANTS SPECIES IN USED

Rafati and coworkers cited in [18] evaluated the ability to uptake Cr from the soil by different organs of *Populous alba* and *Morus alba*. Leaves accumulated higher levels of Cr than stems or roots. However, neither *P. alba* nor *M. alba* showed potential of Cr phytostabilization, since presented T

F > 1 and root B C F < 1; also these plants are not suitable for phytoextraction as they presented a B C F < 1. Reference [53] conducted an experiments to assess the ability of the water fern *Azolla pinnata* to survive when exposure to different diesel concentrations. The results clearly were shown that whenever the concentration increased the withered plant also increased. Oliveira [18] reported that, *Ipomoea aquatica* is a chromium hyperaccumulator that shows no toxicity symptoms when exposed to high levels of Cr(VI). Up to 28 mg L−1 Cr(VI), *I. aquatica* exhibits uniform absorption characteristics showing over 75% removal of added Cr(VI). Another study [54], assessed the effectiveness *Calendula officinalis* on removing the Cu from the contaminated soil. The concentration of copper showed that translocation (TF) and bio-concentration factor (BCF) was greater than 1 and indicate the plants' ability to tolerate copper concentration.

Khankhane and coworkers [55] conducted an experiments in soil as well as in hydroponic system to explore the phytoremediation potential of *Arundo donax*. The authors concluded that a significant and better uptake of Cd was observed in the hydroponic system as compared to soil cultures as Bio Concentration Factor (BCF) and Translocation Factor (TF) were more than 1 but on high exposure of Cd; antioxidant stress was shown by the plant. Wang cited in [19] reported the development and Cu absorption of corn plant (Zea mays L.) which is inoculated or non-inoculated by *Acaulospora mellea*, an *arbuscular mycorrhizal* fungus, by using different doses of Cu-applied pots in laboratory conditions.

Unamuno cited in [19] investigated reed plants' copper adsorption and reported that initial adsorption of Cu was high in the plants vegetative litter; but after 50 min, it decreased drastically. Vymazal cited in [19] claimed that heavy metals levels were reduced in the order of roots > rhizomes ≥ leaves > stems of the reed plants and that the heavy metal (Cd, Cr, Cu, Ni, Pb, and Zn) levels in the shoots and roots plant tissues were the same as those reported for plants growing in natural ecosystems.

IV. CONCLUSION

A phytoremediation is amenable to a variety of organic and in organic compounds may be applied either in-situ or ex-situ. Phytoremediation is considered to be an innovative technology and hope fully by increasing our knowledge and understanding of this intricate clean up method, it will provide a cost effective, environment friendly alternative to conventional cleanup methods.

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