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Use of Forest Trees in the Treatment of Polluted Soil by Heavy Metals: A Mini Review

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Abstract

Human activities lead to a large accumulation of heavy metals in the soil which comes from industrial activities such as mining smelting refining manufacturing processes and waste resulting from excessive use of chemical fertilizer and vehicle exhausts. So, soil pollutants especially with heavy metals can be treated using different types of plants; such as forest trees and grasses. These plants can tolerate soil pollutants at high concentrations in their biological tissue, and treat pollutants by absorbing and accumulating heavy metals in their living tissues. Therefore, in this article, we reviewed several forest tree species, that showed high resistance in the absorption and accumulation of heavy metals, such as genus Eucalyptus, Acacia, Salix, Populus, Tamarix, Melia, Dalbergia, Leucaena, Acer, Fraxinus, and Thuja. It has been noted that planting forest trees with high biomass that resist high concentrations of heavy metals in soil, works to rid the soil of these pollutants. This is the latest and best technology for treating soil pollution. In particular, it is unique from its counterparts in its environmental friendliness, economic benefits, and other returns resulting from plant cultivation. Therefore, applying phytoremediation techniques that benefit is the best and safest for the environment and living organisms.

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Introduction

Environmental pollution results from the increasing human numbers in urban cities and their spread over large areas on the surface of the Earth, which is necessary for the development of various technologies. In various areas of life, which have grown and increased in a negative and unregulated manner, causing the problem of the times that have harmed humans themselves and other living organisms (Al-Khazan and Al-Zlabani, 2019).

Plant techniques have been used around the world to restore damaged ecosystems, as woody trees with short life cycles have helped remediate polluted soil and water. Forest stands with short life cycles have a high ability to grow rapidly with larger biomass than others, thus achieving plant extraction of heavy metals faster and better than others (Kuzovkina and Volk, 2009). This technology uses naturally occurring processes by which plants and microorganisms in the rhizosphere analysis and trap organic and inorganic contaminants (Pillon-Smits, 2005). Among the tolerant plant species, forest trees have been used for the phytoremediation of heavy metals because they are distinguished from others by their large biomass, genetic diversity, and high economic value, especially their environmental requirements, which are usually available without high costs or effort (Pulford *et al*., 2005).

Recent research preferred to get rid of environments contaminated by heavy metals using trees of forest which do not contribute to the food chain, have short life cycles, are capable of growth and high production of biomass, and have the ability to extract heavy metals accumulated in the soil. This achieves the reclamation of soils contaminated with heavy metals, as well as the production of bioenergy represented by tree biomass (Suman *et al*., 2018; Abdelsalam *et al*., 2019; Gebretsadik *et al*., 2020). The use of specific plants to remove and reclaim multiple pollutants from the soil and surrounding environment is called phytoremediation. This process includes more applications such as Phytodegradation, Phytostabilization, Phytoextraction, (phytoaccumulation), Rhizofiltration, and Phytovolatization. Plants have a specific and highly efficient metabolic feature that sequesters nutrients and elements from soil. Processes for transporting and storing nutrients elements from the soil same as those used by plants to absorb, transport, and store poisonous materials. The system of roots can absorb nutrients and poisonous elements even at very low levels in the soil with the help of factors such as chelating substances, chelating reactions, hydrogenation, and redox (Tangahu *et al*., 2011). Furthermore; a ratio of phytoextraction is considered important in selecting species capable of phytoremediation (Zhao *et al*., 2003). It is known that more species of plant have a high ability to accumulate metals in their parts, and these plant species can concentrate heavy metals such as cadmium, zinc, cobalt, manganese, nickel, and lead 100 to 1000 times Superior to other types that do not have this particular, and they are prepared woody trees species are among the best plants in this matter in addition to timber production (Erdei *et al*. 2005; Cho-Ruk *et al*., 2006; Ang *et al*., 2010). Therefore, hyperaccumulators were called for species of plant that can concentrate more heavy elements and maintain a growth rate (Baker *et al*., 2020). heavy metals accumulation in plant tissues at different concentrations does not show any toxic symptoms and at the same time; They reduce soil and wastewater pollution (Yasar *et al*., 2010; Houda *et al*., 2016).

Our article targeted phytoremediation technology, which is one of the methods of treating soil pollution with heavy metals is a very influential a global problem that greatly affects plants that enter the food chain for animals and humans, since most forest trees do not enter the food chain; therefore, we encourage the use of forest trees to treat soil contaminated with heavy metals.

Some plant mechanisms for treating soil from heavy metals

Phytoextraction: It refers to plants that concentrate heavy elements in the shoot at a higher rate than in the root system. It depends on the type of plant and the nature of the conditions surrounding it increasing the duration of plant exposure to heavy elements encourages their occurrence, which leads to a reduction in the activity of antioxidants and the plant’s other means of defense, and thus facilitates the transfer of heavy elements to the vegetative parts to accumulate in special gaps found in the cell walls, which are one of the most important sites for isolating heavy elements (Heidari and Sarani, 2011). The reason for this is the plant's ability to adapt to grow in environments contaminated with heavy metals, which made it increase its resistance to soil contaminated and adapt to new growing conditions, by developing defensive means and preparing antioxidants to limit the action of toxins by trapping them in the gaps (Al-Salmany and Ibrahim, 2021; Dmuchowski *et al*., 2014).

Phytostabilization: This means plants that concentrate heavy elements in the root system at a higher rate than the shoot. Plant roots work to chelate and bind elements in the nearby soil (Rhizosphere). Most uptake of soil pollutants occurs in the epidermal layer of the cap, and the root cap lacks the Casparian stripe that controls the movement of water and salts through the cell wall lumen of phloem to the xylem, so it facilitates the transport of minerals through the cell walls directly to the xylem (Khamis *et al*., 2014). Metal chelates or metal-like particles present in plant cells can help sequester heavy metals within root cell vacuoles (Al-Salmany and Ibrahim, 2021; Fulekar *et al*., 2009).

Heavy metal particles permeate the soil, exceeding their natural limits to form in high concentrations that are harmful to the plants that absorb them. They directly affect human and animal health and microorganisms. Heavy elements include metals and metalloids whose density exceeds 5 gm cm-3, such as lead, cadmium, zinc, copper, and arsenic. Plants have mechanisms and means of defense against pollutants, such as chelating agents (Phytochelatins) (Suman *et al*., 2018; Luo, 2019). Plants follow various mechanisms to reduce and limit the spread of pollutants and heavy elements in the environment. They reduce the mobility of heavy elements in the soil, limiting the process of washing out of the soil, absorption by the soil, and transportation, as well as their fixation in plant roots. This is called phytostabilization, as well as their extraction process (El-Amier and Alghanem, 2018). Poplar and Willow, which belong to the Willow family, are of high value as sources used for the phytoremediation process, and often species of Eucalyptus, Birch, Robinia and Paulownia trees, which are recommended in the process of phytoextraction and bioconcentration of heavy metals in a large way, and for their ability to produce high biomass vitality within a short period (Pajević *et al*., 2016).

Reviewing some studies conducted on forest trees suitable for treating polluted soils

Dos Santos Utmazian and Wenzel, (2007) conducted a study for genus Salix spp. *and* Populus spp. to evaluate the extent of the ability to collect cadmium and zinc from soil contaminated with these elements. Researchers concluded that *S. smithiana* is a good species in phytoextraction applications for cadmium and zinc.

Aba-Alkhil and Moftah, (2013) planted seeds of *Tamarix aphylla*, *Acacia coriacea* and *Acacia salicina*, they were treated with concentrations of 0, 10, 100, and 1000 mg kg^{-1} dry soil for each of cadmium and lead. The results showed that species *A. coriacea* was identified as the most resistant to toxicity and whose cultivation is recommended as a soil treatment for pollution with cadmium and lead. This is because it showed high resistance to toxicity with these elements, and it was followed by *A. salicina* in terms of its tolerance to the two elements, while *T. aphylla* was well tolerant, but less tolerant compared to the two types of Acacia.

In the study of Bajwa, (2014) on seedlings of *Melia azedarach*, *Eucalyptus tereticornis*, *Dalbergia sissoo and Leucaena leucocephala*, trees were treated with cadmium concentrations of zero, 10, 20, 40, 80 and 120 and lead concentrations of 0, 30, 60, 120, 180, and 240 $mg.kg^{-1}$ from dry soil. Lucinia gave good absorption for lead and cadmium. The amount of lead and cadmium absorption in Eucalyptus reached 50.86 and 38.91 mg $seedlings^{-1}$ at concentrations of 240. and 120 $mg.kg^{-1}$, sequentially. We concluded that *L. leucocephala* could be classified as the best of the four types studied for phytoextraction of cadmium and lead in soil.

Yang *et al*. (2015) conducted a study on the tolerance of 39 willow cultivars to high cadmium concentrations. The results showed that the value of shoot tolerance index (TIs) was limited to 0.09-1.85, while the value of root tolerance index (TIr) was limited between 0.27-1.99 for most species. As for cadmium concentrations in dry weight, they ranged between 64.7-663.7 micrograms g^{-1} in the leaves, and in the stem ranged between 118.0-308.4 micrograms g^{-1}, and were between 163.9-1426.4 micrograms g^{-1} in the roots of most species, and the amount of the transfer factor varied in the leaves, it ranged between 0.09-1.72, and between 0.15-1.08 for the transfer factor in the shoot (TFs). As for the total cadmium content present in the dry weight of the shoot, it varied between 29.8-2726.52 micrograms per $plant^{-1}$ for most plants, and when looking at the values of each of the TFs and TIr, TIs, cadmium concentrations and cadmium content of shoots, it was found that five willow cultivars, *Salix babylonica, S.*

suchowensis, *S. matsudana*, and *S. integra*, are the best and most resistant to high concentrations of cadmium, which outperformed other types in the phytoextraction process. These results encourage the selection of the five willow seedlings in the phytoremediation process, which absorbed the highest concentrations of cadmium in their tissues.

As for the study was conducted to evaluate the ability of broad-leaved forest species (Hardwood), such as *Acer cappadocicum* and *Fraxinus excelsior*, and needle-leaved forest species (Softwood), such as *Thuja orientalis* and *Cupressus arizonica*, to extract lead from the soil, by researcher Abbasi *et al*., (2016). Seedlings were planted in soil and treated with lead element for six concentrations zero, 100, 200, 300, 400, and 500 in unit $mg.kg^{-1}$ in dry soil for six months. The results showed that the highest concentrations of 400 and 500 mg kg^{-1} caused a decrease in the overall growth of all species, but the decrease was It was lower in *T. orientalis* and *C. arizonica*, and the concentration of lead in plant tissues increased with an increase in its concentration in the soil, and the concentration in needle-leaved seedlings was twice what it was in broad-leaved seedlings.

Researchers Mohamed and Khudair (2020) indicated the susceptibility of *Conocarpus lancifolious* seedlings to the treatment of contaminated soil and the accumulation of lead and copper elements in its tissues and various plant parts. It was observed that the plant accumulated heavy metals accompanying an increase in lead and copper concentrations in the soil. The highest accumulation in the root system reached 358.89 mg kg^{-1} at a concentration of 0.4 g kg^{-1}, and 293.67 mg kg^{-1} at a concentration of 1.25 g kg^{-1} for copper.

This experiment was conducted by Mohamed *et al*. (2022) planted *Gmelina arborea*, *Azadirachta indica*, *Tectona grandis* and watering in wastewater. It was found that leaves had the highest Fe content, followed by wood and bark, while wood was the highest in its Zn content, followed by the bark, then the leaves, which had the lowest concentration and which contained the lowest concentration of lead at the same time. The results showed that the three species under study are considered super-accumulating plants and that the highest Phyto-Extraction Ratio (PER) was recorded in *Tectona grandis*, followed by *Gmelina arborea*, then *Azadirachta indica*, for Zn, Fe and Pb. When studying the accumulation of heavy metals along the depth of the soil around the root zone, the results showed that the middle soil depth, which ranged between 30-60 cm, contained the lowest heavy metals concentration, in contrast to surface layer 0-30 cm and the deepest layer 60-90 cm.

As El-Mahrouk *et al.* (2019) studied phytoremediation using *Salix mucronate*, the effect of cadmium, copper, and lead concentrations on vegetative growth, chemical and biochemical compounds, and the possibility of extracting them from the soil, as heavy metal concentrations were added to the seedling soil in the form of aqueous cadmium chloride. $CdCl_2.H_2O$ at concentrations of 0, 20, 40, 60 and 80 mg kg^{-1} dry soil and aqueous copper chloride $CuCl_2.2H_2O$ at concentrations of 0, 50, 100, 150 and 200 mg kg^{-1} as well as lead acetate dissolved in water $(CH_3COO)_2Pb_3H_2O$ at concentrations of 0. 250, 450, 650, and 850 in unit $mg.kg^{-1}$. We showed that big value of the percentage of nitrogen, phosphorus and potassium in the leaves reached 2.53, 0.20 and 2.88%, respectively, when treated with the control, and the percentages of these elements reached 0.83, 0.03 and 1.37%, respectively, at a cadmium concentration of 80 mg kg^{-1}, and the percentages reached 0.72, 0.04 and 1.46% at a lead concentration of 850 mg kg^{-1}.

Table 1. Showing some of the heavy metals polluting soil and species of trees involved in treating them

Heavy metals	Treated trees	Reference
cadmium, zinc, cobalt, manganese, nickel and lead	Eucalyptus, Acacia, Salix, Populus, Tamarix, Melia, Dalbergia, Leucaena, Acer, Fraxinus, Thuja	(Erdei *et al*., 2005; Cho-Ruk *et al*., 2006; Dos Santos Utmazian and Wenzel, 2007; Ang *et al*., 2010; Aba-Alkhil and Moftah, 2013; Bajwa, 2014; Suman *et al*., 2018; Al-Salmany and Ibrahim, 2021)
zinc, and iron	*Gmelina*, *Azadirachta*, and *Tectona*	(Mohamed *et al*., 2022)

Conclusions

We note from what we reviewed in this article that the use of forest trees with high biomass and characterized by short life cycles can treat large concentrations of heavy metals polluting the soil. Therefore, phytoremediation is an ideal method better than non-biotic methods for treating heavy metals in the soil, as it is A method that is safe for the environment and has a high return on economic feasibility. Therefore, afforestation with forest trees with high resistance to heavy metals, such as those mentioned in this article, can treat soil contamination with heavy metals.

Conflicts of Interest

The researchers support that this work does not conflict with the interests of others.

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