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**REVIEW ARTICLE**

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# Toxic materials phytoremediation potential of four common trees in Saudi Arabia: A review

## ABSTRACT:

Heavy metals are the most serious environmental pollutants in the current time as a result of industrial development in several countries. Their pollution is poisoning threat for human, animal and plant life because toxic metals cause several serious ailments. Many techniques have been emerged for the elimination of heavy metal contamination for the environment. Either physical or chemical ones, have limitations such as high cost, long time, logistical problems and mechanical complexity. Phytoremediation alternative solution can be used for heavy metal remediation process because of its advantages as a cost-effective, efficient, and eco-friendly technology based on the use of metal-accumulating plants. Many plant species have a high potential as heavy metals bioaccumulators and can be used for their phytoremediation process. This review focuses on the common phytoremediation mechanisms and the role of four street-tree species (*Moringa oleifera*, *Azadirachta indica*, *Lantana camara* and *Conocarpus erectus*) commonly cultivated throughout the Kingdom of Saudi Arabia (KSA) in phytoremediating various pollutants. Trees description, habitat of growth and their potential to phytoremediate different heavy metals would be discussed.

## KEY WORDS:

Phytoremediation, pollution, street trees, heavy metals.

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## INTRODUCTION:

Soil physical status is significant for the suitable performance of terrestrial ecosystems. Different environmental stresses like salinization, drought erosion, sealing, contamination, loss of organic matter and biodiversity, etc. cause soil degradation (Epelde *et al.* 2009). Principally, soil-contamination with heavy metals is a global crisis of massive significance, due to the varied toxicity, long persistence, bioaccumulation, and biomagnification of metals throughout the food chain (Gomez-Sagasti *et al.,* 2012). Certainly, metal-contamination is negatively disturbing soil health at a large scale, with harmful impacts on vital ecosystem services. Heavy metals are very harmful because of their non-biodegradable nature, long biological half-lives and their potential to accumulate in different body parts. Most of the heavy metals are extremely toxic because of their solubility in water and even at low concentrations have damaging effects on man and animals due to the difficulty for their elimination from the body. Nowadays heavy metals are ubiquitous because of their excessive use in industrial applications. Wastewater contains substantial amounts of toxic heavy metals, which create problems (Chen *et al.*, 2005). Excessive accumulation of heavy metals in agricultural soils through wastewater irrigation, may not only result in soil contamination, but also affect food quality and safety (Muchuweti *et al.*, 2006). In general, heavy metals in urban lands is mainly from traffic and industrial emissions, while the main sources of heavy metals are from mining, drilling, warfare activities, sewage sludge, tannery, electroplating, batteries, pesticides and fertilizers (Wei and Yang, 2010).

The traditional physicochemical methods of soil heavy metals remediation are generally expensive and frequently result in a deterioration of the soil ecosystem. Therefore, in recent decades, the development of eco-friendly biological technologies to economically remediate these soils has been stimulated (Gomez-Sagasti *et al.*, 2012). Bioremediation technique means the use of biological organisms for cleaning contaminated soil and groundwater. The technique is based on accelerate the natural process of biodegradation and cause driving the growth of certain microorganisms using contaminants as a source of food and energy (Azizi *et al.*, 2015). This process is mainly dependent on microbial enzymatic activities in transforming or degrading the contaminants from the soil or water (Liu *et al.,* 2011). It offers a cost-effective remediation technique, compared to other remediation methods, and it is as a natural process does not usually produce toxic by-products. It also provides a permanent solution as a result of complete mineralization of the contaminants in the environment (Perelo, 2010).

Phytoremediation is a renewable technology using either natural or genetically-modified plant species for efficiently restoring contaminated soil and water sources (Arthur *et al.*, 2005; Parmar and Singh, 2015). Advantages of low-cost, eco-friendly and safety are concentrated on in several review articles discussing concepts, types and mechanisms of the phytoremediation process, but there are rare reports concerning the importance of ornamental tress specially those occurring in the streets of the KSA in phytoremediating heavy metals from air and soil. Therefore, this article attempts to account the role of four common trees in KSA in elimination and remediation of toxic pollutants from air and soil.

## Physiological Functions of Toxic Metals in Plants:

The toxicity of a specific metal depends on a range of factors, including the dosage that organisms are exposed to, the method of exposure and duration of exposure. As a well known fact, chemicals at low concentrations may have useful roles during plants growth and development which is called "hormesis" but at high concentrations result in deleterious effects. A lot of heavy metals like cobalt (Co), iron (Fe), manganese (Mn), molybdenum (Mo), nickel (Ni), zinc (Zn), and copper (Cu) are essential micronutrients with beneficial roles during normal growth and contribute in redox homeostasis, electron transport and many metabolic processes in plants, whereas, others like lead (Pb), cadmium (Cd), chromium (Cr), mercury (Hg), and arsenate (As) are enormously toxic for plants (Rai *et al.,* 2005). The result of a recent study showed that the mean values of the metals concentrations in surface soil nearby an oil refinery in KSA were in the order:
Cd > Mo > Tb > Ce > Hf > Eu > Yb > U > Sm > Rb > Cr > Ni > Pb > Sc > Cs > Zn > Lu > Co. The mean values of Cd (39.9 mg/kg), Mo (13.2 mg/kg), Eu (4.01 mg/kg), Hf (6.09 mg/kg), Tb (8.23 mg/kg), and Yb (3.88) in soil samples were higher than the background values in soil and the world average (Alshahri and El-Taher, 2018). Cd is commonly known toxic metal; though some reports confirmed that Cd achieves essential physiological roles in hyperaccumulators (Verbruggen *et al.,* 2013). In *Arabis paniculata*, proper concentrations of Pb, Zn, and Cd significantly prompt the biomass and chlorophyll production (Tang *et al.,* 2009). In the root of foraging hyperaccumulator *Sedum alfredii*, potent responses for Zn and Cd were detected, with 90% of its root biomass allocated to Zn and Cd-rich patches when grown in a medium with a heterogeneous distribution of Zn and Cd (Liu *et al.,* 2010). In *Potentilla griffithii*, the addition of Zn to the growth medium distinctly lowered Cd concentration in roots and enhanced the translocation of Cd to the aerial parts, particularly leaf petioles. This refers to the strong competition in the plant root between Cd and Zn uptake and their efficient translocation to the shoot system (Qiu *et al.*, 2011). Another study on *Picris divaricata* showed that chloroplast ultrastructure remained unaffected after the exposure to high Cd levels, though the mesophyll cell size showed some reduction, which is a good indicator on high Cd levels tolerance by the chloroplast and the enzymes of carbon assimilation (Ying *et al.*, 2010).

## Mechanisms of phytoremediation:

Phytoremediation of heavy metals from the contaminated sites generally could be through any one or more of the following mechanisms: phytoextraction, phytostabilization, phytovolatilization, rhizofitration, and phytodegradation (Fig. 1).

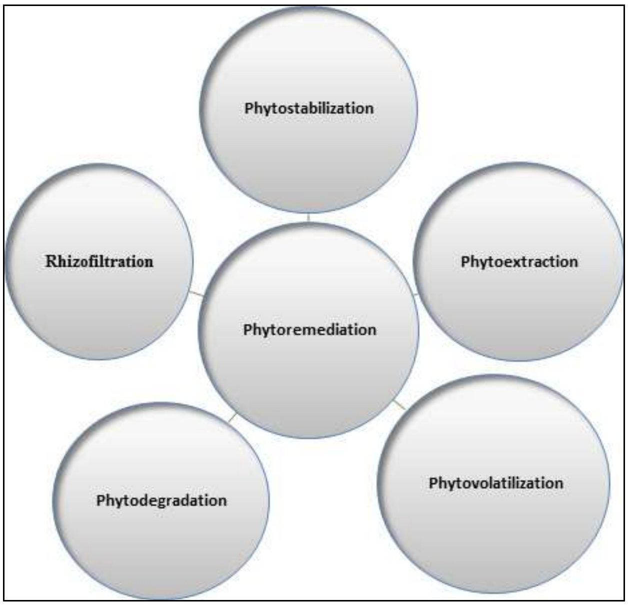

Fig. 1. Diagrammatic for relationship of various phytoremediation mechanisms.

## Phytoextraction:

Phytoextraction, also named phyto-accumulation, phytoabsorption or phyto-sequestration. It means the absorption of contaminants from soil or water via plant roots and their mobility and accumulation in aboveground tissues, that simply burned after harvesting for energy production and possible restoration of the metal from the ash (Rafati *et al.*, 2011). The metal-accumulating plants can be sown or transferred into soils greatly polluted with these pollutants and subsequently cultivated with conventional agricultural practices. Salt *et al.* (1995) stated that phytoextraction costs are ten times lesser than common remediation methods. Some metals like Pb, Cd, Ni, Cu, Cr, and V were guaranteed to be totally removed from the soil by phytoextraction. Unfortunately, phytoextraction technique application is limited to metal slightly or fairly contaminated places, as a result of limited plant growth inside heavily contaminated places (Padmavathiamma and Li, 2007). Plants used in phytoextraction be supposed to have specific characteristics like (a) high rate of growth and biomass, (b) deep and greatly branched root systems, (c) high acclimation to different environmental conditions, (d) simplicity of cultivation and growing (e) more or less unpalatable by animals to prevent translocation and accumulation of metals in food chain (Seth, 2012).

Phytoextraction could be coupled with forestry and bioenergy production as income making processes (Van Ginneken *et al.,* 2007). For instance, castor bean had been reported to be Cd and Pb accumulator (Romeiro *et al.*, 2006; Melo *et al.*, 2009). Phytoextraction of Cd by carambola (*Averrhoa carambola*) tree is a supreme method for soils decontamination from Cd, because it has estimated that 50% of Cd in slightly contaminated soil could be extracted within 13 years (Li *et al.,* 2009). Also, Cd uptake by *Moringa oleifera* was found to be 168.5 mg $kg^{-1}$ in 30 days old plant roots and 19.9 mg $kg^{-1}$ Cd in shoots at 5 mM Cd concentration in soil (Yadav and Srivastava, 2017).

## Phytostabilization:

Phytostabilization, also called as phytoimmobilization, is the use of certain plants in stabilizing heavy metals in polluted soils (Singh, 2012). This practice could be used in modifying the organic and/or inorganic metal-pollutants into the stable form, lowering their hazards to the environment. The main objectives of this process are to (a) reduce the leaked water amount into the soil, which could form detrimental leachate, (b) constitute barrier preventing direct contact with the polluted soil and (c) prevent soil weathering and dispersal of the heavy metals to other places (Raskin and Ensley, 2000). Plants commonly used in phytostabilization are characterized by slow translocation rate of the contaminants from the root to the aerial parts, fast growing, having deeply branched root systems and extensive shoot system, and must be adaptable to environmental and biological stresses (Ismail, 2012). In this circumstance, willow plant proved high capability towards phytostabilization of heavy metals-contaminated soils (Tack *et al.*, 2005). Some metals, like Cd and Zn, were found to be accumulated principally in roots, but their amount in the shoots increased following the increase of their concentration in the soil (Soudek *et al.*, 2012). Phytostabilization could be used in the reclamation of bare sites with high metal contamination levels. Once a tolerant plant community has been established, the soil became stable and consistent to oppose the dispersal of the pollutant metals, hence the leakage of the contaminants into the soil is also reduced. Phytostabilization is the most appropriate because the elimination of contaminated biomass is not required, and it is very useful in preserving ground and surface waters (Wuana and Okieimen, 2011).

## Phytovolatilization:

Phytovolatilization could be described as the uptake of soil contaminants and transforming them into volatile forms through their transpiration into the ambient atmosphere (Jadia and Fulekar, 2009). Phytovolatilization was applied with many contaminants like mercury; inorganic volatiles as selenium and arsenate; and organic volatiles like trichloroethene. Phytovolatilization is characterized by evolving toxic pollutant into the atmosphere following their transformation into less toxic forms. However, rainfall may cause the re-deposition of the polluting substances over again in aquatic systems (Nikolic and Stevovic, 2015). Phytovolatilization has been proved to be most effective in the removal of some organic volatiles as 1,4-dioxane (Ferro *et al.*, 2013). Genetically engineered plants like *Arabidopsis thaliana*, *Nicotiana tabacum*, and *Liriodendron tulipifera* have been reported to be used in mercury phytovolatilization from polluted sites (Ali *et al.*, 2013). These plants are cloned with mercuric reductase gene “merA”. Additionally, a bacterial gene called organomercurial lyase (merB) was found to be used in methyl-mercury detoxification. Nevertheless, both genes can be used for mercury detoxification, merB cloned plants are moresafe as this gene prevents methyl-mercury to be introduced into the food chain. Phytovolatilization could be used for selenium detoxification through the alteration of elemental selenium into organic seleno-amino acids (seleno-cysteine and seleno-methionine). Seleno-methionine is further converted into dimethylselenide which is then volatilized to the atmosphere (Terry *et al.*, 2000). *Brassica* species were most effective when used in phytovolatilization of selenium (Banuelos *et al.*, 1997).

### Rhizofiltration:

Rhizofiltration is the use of plants in absorption, concentration, and deposition of contaminants from aqueous sources in their roots (Schwitzguébel, 2001). Rhizofiltration could harnessed principally in the decontamination of wastewater, extracted groundwater, and surface water containing low concentrations of contaminants. The best plant species for rhizofiltration should have profound and extensively branched roots with high capacity to take up toxic metals from solution throughout a long time. These plantsare supposed to be characterized by large biomass production (1.5 kg.month.m$^2$ of water surface) (Dushenkov *et al.*, 1997). During rhizofiltration, the plant roots take up contaminant and transmit it into other plant parts, according to the pollutant nature, its concentration, and the plant species. Rhizofiltration is achieved by the aid of particular compounds synthesized inside the root that allow heavy metals to be accumulated in the plant body. The contaminants adsorption on the root surfaces is basicallydependant on root exudates and soil pH (Krishna *et al.*, 2012). The principally used plant species in rhizofiltration includes the Indian mustard, sunflower, and maize (Brooks and Robinson, 1998). After metal rhizoextraction from the polluted sites, the used plants can be used for many purposes like energy production and metal chemical extraction (Ni, Cu, and Au) (Verma *et al.*, 2007; Kathi, 2015).

### Phytodegradation:

Phytodegradation, also recognized as phytotransformation, is the contribution of plant metabolic processes in the internal or external breakdown of organic contaminants. In other words, the involvement of specific metabolic processes in the breakdown of complex organic compounds into simpler forms that can be simply absorbed by the plant (Suresh and Ravishankar, 2004). A number of plant enzymes like peroxidase, nitroreductase, laccase, nitrilase, and dehalogenase are involved in such phytodegradation process (Morikawa and Erkin, 2003).

Plants used in phytodegradation should be characterized by (a) greatly branched roots for secreting a considerable amount of degradable enzymes, (b) tolerance to high pollutants levels, (c) fast growth rate, and (d) a relatively high biomass (Wang and Chen, 2007). The microorganisms found in the root medium could improve organic pollutants degradation in the soil. Additionally, discharge of some exudates like sugars, amino acids, and flavonoids by root surface could prompt microbial activity 10 – 100 folds, compared to the activity in bulk soils (Ali *et al.*, 2013). Phytodegradation is more specific to organic pollutants since the heavy metals have non-biodegradable characters. The most recent studies have paid attention to the use of phytodegradation in the elimination of many organic compounds like herbicides and insecticides (Singh and Jain, 2003).

### Advantages and disadvantages of phytoremediation:

The advantages of phytoemediation are numerous when compared to other technologies as some of these advantages are:

1. Predominantly feasible and widely accepted (Marmiroli and McCutcheon, 2003).
2. Solar-driven (Ali *et al.*, 2013).
3. Applicable with hydrophobic compounds like organics (Cofield *et al.,* 2007).
4. Quite cost-effective (Cornish *et al.*, 1995).
5. Even if the plants are contaminated and unusable, the resultant ash is just about 2–3 tons/ 500 tons of soil (Ghosh and Singh, 2005).
6. The used plants reduce erosion by wind and water (Cunningham *et al.*, 1995).
7. Produces recyclable metal-rich plant residue (Muthusaravanan *et al.*, 2018).
8. Removes secondary air or waterborne wastes (Lili and Hui, 2007).

However, phytoremediation grapples some limitations, which are listed below:

1. Because of the short roots, the plants can decontaminant the soil or the groundwater near the surface (Padmavathiamma and Li, 2007).
2. Trees roots are deeper and can slightly remove deeper contamination than plants (on average 10 - 15 feet), but cannot remediate deep groundwater without additional design work (Pulford and Watson, 2003).
3. Plants used in toxic materials remediation may get into the food chain (Arthur *et al.*, 2000).
4. The compounds extracted from soil and groundwater may cause air pollution problem (Sakakibara *et al.*, 2010).
5. Imperfect elimination of atmospheric contaminants (Garbisu *et al.*, 2002).
6. Can take long time to clean up a site (Stomp *et al.*, 1994).

## Selection criteria of plant species for phytoremediation:

Choice of plant species for phytoremediation depends on a number of criteria such as their ability to remediate the wanted contaminants, to increase their remedial properties and their adaptability to withstand site-specific factors (Cunningham and Ow, 1996). The most favoured vegetation characteristics include adaptation to local climates, depth of the plant's root structure, ability of the species to thrive in soil they are grown in, ability to extract or degrade the concerned contaminants to less toxic form, fast growth rate, ease of planting and maintenance and the uptake of appropriate volumes of water by evapotranspiration (Ashraf *et al.*, 2010). Care should be taken into consideration during the selection process to prevent the introduction of non-native species into the areas where those species are upset (Cunningham *et al.*, 1995). Plant species that are benign under most circumstances may become a problem when introduced into a new area (Kennen and Kirkwood, 2015). The plant species which is selected for use at contaminated sites have some maintenance requirements, which includes the frequency with which the plant must be mowed; the need for fertilizer; and the need for replanting, pruning, harvesting and monitoring programs (Sas-Nowosielska *et al.*, 2004).

## The flora of Saudi Arabia:

Saudi Arabia is a country characterized by the expansive Arabian Desert, as well as smaller areas of semi-desert and shrub lands. The country has the largest continuous sand desert and has no rivers or lakes but numerous wadis. Saudi Arabia has a desert climate with high temperatures during the day and low annual rainfall. The flora of Saudi Arabia consists of 2284 species distributed across the country. Most of the species grow on mountains, wadis, and meadows. Only 2.5% of the plant species are endemic to the country despite the size of Saudi Arabia. The flora of Saudi Arabia, as well as the other countries in the peninsula, has been neglected for a long time due to its arid climate. The first attempt to cover the flora of Saudi Arabia was in the seventeen's of the last century (Alfarhan *et al.,* 1998). A total of 2284 species including native and introduced plants have been reported from various habitats of Saudi Arabia (Migahid, 1988; Collenette, 1999; Thomas, 2011).

Street trees, defined as trees growing along the public street and managed by the city, account for a relatively small fraction of the entire urban forest, but are prominent because of their visual and physical impacts on the quality of urban life. The afforestation movement in Saudi Arabia has been started mostly before 50 years. It has been noticed that there a change in the selection of tree species used in afforestation of some cities throughout KSA within a short period of time without justification. For instance, there was an intense spread of some tree species on a large scale in the country at the expense of other species that were extensively used before. For example, the increase of planting *Conocarpus erectus* at the expense of all tree species that were grown before such as *Ziziphus spina*, *Albizia lebbeck* and *Prosopis spp* (El-Juhany and Al-Shaikh, 2015). That change in the nature of vegetation distribution may affect the ecosystem balance, elements cycle and soil physic-chemical properties (Sundaravalli and Paliwal, 2002). Some of these trees and their phytoremediation potential are discussed below.

## *Moringa oleifera* (moringa):

*Moringa oleifera* Lam, is a fast-grown tree which is native to India and Pakistan, and it is widely cultivated in dry tropical areas of the Middle East and Africa (Morton, 1991). *M. oleifera* is a small, graceful, deciduous tree with sparse foliage, often resembling a leguminous species at a distance, especially when in flower, but immediately recognized when in fruit. The tree grows to 8 m high. Bole crooked, often forked from near the base. Bark smooth, dark grey; slash thin, yellowish. Twigs and shoots shortly but densely hairy. Crown wide, open, typically umbrella shaped and usually a single stem; often deep rooted. The wood is soft. Leaves alternate, the old ones soon falling off; each leaf large (up to about 90 cm long), with opposite pinnae, spaced about 5 cm apart up the central stalk, usually with a 2nd lot of pinnae, also opposite, bearing leaflets in opposite pairs, with a slightly larger terminal leaflet. Leaflets dark green above and pale on the under surface; variable in size and shape, but often rounded-elliptic, seldom as much as 2.5 cm long (Orwa *et al.*, 2009). Moringa is a multi-purpose plant which can be used as field or fodder crop, crop growth enhancer, biopesticides, biogas, water purification, phytomedical source etc. (Suarez *et al.*, 2003; Nouman *et al.*, 2013). Many research papers paid great attention to the phytoremediation potential of moringa tree and recommended its use in purification of water, air and soil in agricultural and rural areas around the world (Mataka *et al.*, 2006; Adelaja *et al.*, 2011; George *et al.*, 2016). Besides being a good source of protein, vitamins, oils, fatty acids, micro-macro minerals elements and various phenolics, it is also reported as anti-inflammatory, antimicrobial, antioxidant, anticancer, cardiovascular, hepatoprotective, antiulcer, diuretic, antiurolithiatic, and antihelmintic (Farooq *et al.*, 2012). Its multiple pharmaceutical effects are capitalized as therapeutic remedy for various diseases in traditional medicinal system. Literature exploration showed that different parts of moringa including biomass, seeds, seed husks, bark and leaves have been reported to have biosorbent properties that chelate heavy metals from aqueous solutions, leachate and lake water (George *et al.*, 2016). Heavy metals chelating ability exhibited by the different parts of moringa was accredited to the phytochemical constituents of this tree (George *et al.*, 2016). The mechanisms used in phytoremediation of the most widely spreaded heavy metals by *M. oleifera* are summarized in table 1.

Table 1. Phytoremediation mechanisms of metal detoxification by the phytometalloid *Moringa oleifera*

| Metal | Phytoremediation mechanism | Reference |
|---|---|---|
| Mercury (Hg) | Adsorption of Hg on a modified gum extracted from *M. oleifera* | (Ranote *et al.*, 2018) |
| Nickel (Ni) | Biosorption of Ni ions on hydroxyl, carboxyl, and carbonyl functional groups in *M. oleifera* extract. | (Reddy *et al.*, 2011) |
| Lead (Pb) | Adsorption of Pb on seeds and seed coagulant of *M. oleifera* | (Ravikumar and Sheeja, 2013) |
| Cadmium (Cd) | Phytoextraction of Cd in *M. oleifera* roots and shoots from contaminated soil | (Yadav and Srivastava, 2017) |
| Copper (Cu) | Adsorption of Cu ions on seeds and seed coagulant of *M. oleifera* | (Ravikumar and Sheeja, 2013) |
| Chromium (Cr) | Adsorption of Cr on seeds and seed coagulant of *M. oleifera* | (Ravikumar and Sheeja, 2013) |
| Iron (Fe) | Phytoextraction and accumulation of the heavy metal Fe in various plant organs of *M. oleifera*. | (Amadi and Tanee, 2014) |
| Zinc (Zn) | Phytoextraction and accumulation of the heavy metal Zn in various plant organs of *M. oleifera*. | (Amadi and Tanee, 2014) |

## ***Azadirachta indica* (neem):**

Neem (*Azadirachta indica* L.) tree is a member of the family *Meliaceae* which is commonly distributed in tropical and semitropical regions like India, Bangladesh, Pakistan, and Nepal. It is a fast-growing tree with 20 - 23 meters tall and the trunk is straight with a diameter around 4 - 5 feet. The leaves are compound, imparipinnate, with each comprising 5 - 15 leaflets. Its fruits are green drupes which turn golden yellow on ripening in the months of June-August. Neem tree is well adapted to a wide range of climatic and soil conditions and has gained worldwide recognition for its pharmaceutical and pesticidal properties (Girish and Shankara, 2008). The world's largest pure neem plantations are available in the plains of Arafat, Saudi Arabia where 50,000 neem trees were planted to provide shade from the blazing summer sun for the millions of Muslim pilgrims (Mridha and Al-Suhaibani, 2014). Neem tree has been introduced into KSA to minimize the desertification under changing climatic conditions and to improve the environmental condition of the country (Mridha and Al-Suhaibani, 2014). Many reports were introduced showing the phytoremediation potential of neem using specific remediation mechanisms (Table 2).

Table 2. Phytoremediation mechanisms of metal detoxification by the phytometalloid *Azadirachta indica*

| Metal | Phytoremediation mechanism | Reference |
|---|---|---|
| Mercury (Hg) | *A. indica* tree bark was found to be efficient in the removal of Hg ions from aqueous solution. | (Tiwari *et al.*, 1999) |
| Chromium (Cr) | *A. indica* tree bark was found to be efficient in the removal of Cr ions from aqueous solutions. | (Tiwari *et al.*, 1999) |
| Lead (Pb) | *A. indica* leaf powder is a very efficient remover of Pb from an aqueous solution. | (Bhattacharyya and Sharma, 2004) |
| Cadmium (Cd) | *A. indica* leaf powder has a good potential for adsorption of Cd from the aqueous medium. | (Sharma and Bhattacharyya, 2005) |
| Zinc (Zn) | *A. indica* leaf powder presents sufficient adsorption capacity for Zn ions from aqueous solution. | (Arshad *et al.*, 2008) |
| Copper (Cu) | *A. indica* leaf powder serves as a potential adsorbent to remove Cu ions from aqueous solutions. | (Febriana *et al.*, 2010) |
| Iron (Fe) | *A. indica* tree is potentially useful for remediating Fe from contaminated soils. | (Abdullahi *et al.*, 2016) |
| Nickel (Ni) | *A. indica* tree is potentially useful for remediating Ni contaminated soils. | (Abdullahi *et al.*, 2016) |

## ***Lantana camara L.* (lantana):**

*Lantana* is a genus comprises both herbaceous plants and shrubs, containing about 150 species and belongs to the family *Verbenaceae* (Ghisalberti, 2000). *Lantana camara* is an evergreen climbing aromatic shrub, and is considered to be one of the most important medicinal plants of the world (Sharma *et al.*, 2000). It can grow up to 2-4 meters in height under normal conditions but can climb up to 15 meters in height with the support of surrounding vegetation. *L. camara* is native to tropical regions of America and

Africa, but now, it has been introduced as an ornamental plant in most countries worldwide including Saudi Arabia and has been completely naturalized in most tropical and subtropical parts of the world as it can easily grow and survive in variety of agro-climatic conditions (Sharma *et al.*, 1981). *L. camara*has been widely used in traditional medicine for the treatment of many diseases (Sathish *et al.*, 2011). In several studies, *L. camara* has introduced as an emerging metallophyte for remediation of heavy metal contaminated soils, some of these studies are summarized in table 3.

Table 3. Phytoremediation mechanisms of metal detoxification by the phytometalloid *Lantana camara*

| Metal | Phytoremediation mechanism | Reference |
|---|---|---|
| Mercury (Hg) | *L. camara*is an excellent phytoextractor of Hg and accumulates it with high concentrations in its shoot. | (Kamble and Bhamburdekar, 2016) |
| Nickel (Ni) | *L. camara*is a potential accumulator for Ni in their shoot via phytoextraction from contaminated soil. | (Deepa *et al.*, 2015) |
| Lead (Pb) | *L. camara*is a potential phytoremediator of Pb contaminated soils via phytoextraction and phytostabilization. | (Alaribe and Agamuthu 2015) |
| Cadmium (Cd) | *L. camara*had a strong root retention capacity and phytoextraction of Cd. | (Fang *et al.*, 2014) |
| Copper (Cu) | *L. camara*is an efficient phytoextractor of Cu, with effective chelators for phytoextraction of metals. | (Pandey and Bhattacharya, 2018) |
| Chromium (Cr) | *L. camara*is an efficient phytoextractor of Cr, with effective chelators for phytoextraction of metals. | (Pandey and Bhattacharya, 2018) |
| Iron (Fe) | *L. camara*follows the phytoextraction strategy for Fe and most of the metals by translocating them into the harvestable parts. | (Pandey *et al.*, 2016) |
| Zinc (Zn) | *L. camara*is an efficient phytoextractor of Zn, with effective chelators for phytoextraction of metals. | (Pandey and Bhattacharya, 2018) |

## ***Conocarpus erectus* L.:**

*Conocarpus erectus* L. is a species belonging to the family *Combretaceae* and is commonly called button wood or button mangrove. *C. erectus*is a tropical and subtropical evergreen tree. It can grow on shorelines in tropical and subtropical regions around the world (Bailey and Bailey, 1976). The species is usually a shrub 1.5 to 4 meters in height but can become a tree up to 20 meters or more in height. The root system consists mainly of laterals and fine roots that are dark brown, weak and brittle, and have a corky bark. The bark is gray or brown, furrowed, fibrous, and moderately thin (about 8 mm). The inner bark is dark cream in colour. Stem wood (specific gravity of 1.0) is hard, heavy, and strong, but branches are fragile. The branches are slender, yellow-green, angled, flattened, or winged. The spirally arranged, elliptic to lanceolate leaves are cartaceous to somewhat fleshy, 2 to 10 cm long, with petioles 3 to 9 mm long. Inflorescences are terminal or axillary panicles of tiny greenish-white flowers grouped in spheroidal heads 3 to 5 mm in diameter. The thin, dry, 5- to 15- mm, two-winged seeds are densely packed into globose clusters (Liogier, 1995).

*Conocarpus erectus* is used in some countries as a folk remedy for anaemia, catarrh, conjunctivitis, diabetes, diarrhoea and fever (Irvine, 1961). Moreover, it is widely cultivated as an ornamental tree in many countries around the world, including Saudi Arabia (Abdel-Hameed *et al.*, 2012). Recent studies on *Conocarpus erectus* revealed its phytoremediation capacity of different heavy metals in polluted soils, some of these studies are summarized in table 4.

Table 4. Phytoremediation mechanisms of metal detoxification by the phytometalloid *Conocarpus erectus*

| Metal | Phytoremediation mechanism | Reference |
|---|---|---|
| Nickel (Ni) | *C. erectus* trees are able to capture Ni from air and absorb it from contaminated soils. | (Safari *et al.*, 2018) |
| Lead (Pb) | *C. erectus* leaves could remediate Pb from air and soil in heavily polluted sites. | (Safari *et al.*, 2018) |
| Cadmium (Cd) | *C. erectus* possess high potential to phytostabilize Cd in its roots in contaminated soils. | (Ashraf *et al.*, 2018) |
| Copper (Cu) | *C. erectus* biochar can be used to enhance metal phytostabilization of Cu contaminated soils. | (Al-Wabel *et al.*, 2015) |
| Iron (Fe) | *C. erectus* biochar can be used in remediating acidic wastewater contaminated with Fe. | (Usman *et al.*, 2013) |
| Zinc (Zn) | *C. erectus* biochar can be used to enhance metal phytostabilization of Zn contaminated soils. | (Al-Wabel *et al.*, 2015) |
| Arsenate (As) | *C. erectus* is not as hyperaccumulator, but it could phytostabilize as during its long-term growth. | (Hussain *et al.*, 2017) |

## CONCLUSION:

Nature is a source of food, shelter and clothing for human. However, the blatant interventions and the industrial and technical revolution led to the emergence of many environmental problems. The most important of which is the pollution of air, water, and soil with heavy metals that negatively affect the biosphere in which humans live. This review focus on four tree species adapted to grow in harsh conditions of climate and pollution. All the studies conducted on these trees showed that they have the ability to remove pollutants through many mechanisms including phytostabilization, phytoadsorption and phytoextraction. Therefore, this study recommends the expansion in the cultivation of these trees in the contaminated sites to get rid of the environmental effects of the toxic metal pollutants.

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# قدرة أربعة من الأشجار الشائعة في المملكة العربية السعودية على المعالجة الحيوية للمواد السامة

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المعادن الثقيلة هي أخطر الملوثات البيئية في العصر الحالي نتيجة للتنمية الصناعية في العديد من البلدان. يمثل التلوث بالمعادن الثقيلة تهديدًا للحياة البشرية والحيوانية والنباتية حيث تتسبب هذه المعادن السامة في العدي دمن الأمراض الخطيرة. وقد ظهرت عدة تقنيات للقضاء على ملوثات المعادن الثقيلة من البيئة. والتقنيات الأكثر شيوعًا، سواء الفيزيائية أو الكيميائية، يحدها قيود التكلفة العالية والوقت الطويل والمشاكل اللوجيستية والتعقيد الميكانيكية. لذا يتحول العالم لاستخدام المعالجة الحيوية النباتية كأسلوب بديل لمعالجة التلوث بتلك المعادن الثقيلة، حيث تمتاز هذه الطريقة بفاعليتها من حيث التكلفة واعتبارها طريقة صديقة للبيئة. وهناك العديد من الأنواع النباتية التي لديها إمكانات عالية للتراكم الحيوي للمعادن الثقيلة ويمكن استخدامها في عملية المعالجة الحيوية لها. وتركز هذه المقالة على آليات لمعالجة الحيوية المشتركة ودور أربعة أنواع من الأشجار التي تنمو في شوارع المملكة العربية السعودية في معالجة العديد من الملوثات وسيتم مناقشة الوصف النباتي لهذه الاشجار وبيئة النمو بالإضافة إلى قدرتها على المعالجة الحيوية للمعادن الثقيلة المختلفة.