International Journal of Chemical Studies

P-ISSN: 2349–8528
E-ISSN: 2321–4902
IJCS 2019; 7(4): 639-641

Received: 19-05-2019
Accepted: 21-06-2019

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Role of plants in phytoremediation of heavy metals from contaminated soils: A review

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Abstract
Heavy metal are the major pollutants which inhibit the growth and development of the plant and other crops, they are also responsible for the adverse effect on human and environment.
Phytoextraction, rhizofiltration and phytovolatilization are the methods which remove the heavy metals from the soil and reduce their negative effect on soil as well crops. Sunflower, soyabean, *B. juncea*, brinjal, *T. rotundifolia* sub spp. etc are the plants which extract the different heavy metals from soil through their developed roots and this method of metals extraction from soil is cheap and ecofriendly which is far better than the other expensive methods. Induced phytoextraction method may increase the metal content in soil because they dissolve water soluble contents. The extracted metal contents are accumulated in the leaves of the crop which can easily be analyzed by instrument in laboratory. The phytoextraction and other technique eventually increase the productivity of the land.

Keywords: Plants, phytoremediation, heavy metals, contaminated soils

Introduction
Phytoremediation is the direct use of living green plants for in situ, or in place, removal, degradation, or containment of contaminants in soils, sludge's, sediments, surface water and groundwater. Phytoremediation is:

- A low cost, solar energy driven cleanup technique.
- Most useful at sites with shallow, low levels of contamination.
- Useful for treating a wide variety of environmental contaminants.

Toxic metal pollution of soils is a major environmental problem, and most conventional remediation approaches do not provide acceptable solutions. The use of specially selected and engineered metal- accumulating plants for environmental clean-up is an emerging technology called Phytoremediation. Three subsets of this technology are applicable to toxic metal remediation:

1. **Phytoextraction:** The use of metal-accumulating plants to remove toxic metals from soil.
2. **Rhizoflltration:** The use of plant roots to remove toxic metals from polluted waters and
3. **Phytostabilization:** The use of plants to eliminate the bioavailability of toxic metals in soils. The continuous increase in industrial activities has contaminated the soil with heavy metals such as cadmium, chromium, copper, mercury, lead, arsenic, nickel, and zinc and is non-degradable and hazardous to life. Many physiochemical methods have been proposed to remove metals from soil, but no method is completely safe and satisfactory. Phytoextraction or phyto-accumulation has emerged as a promising technique for soil remediation that can readily absorb heavy metals and purify the soil of its contaminants. Plants have a natural mechanism to take up and store nutrients according to their bioavailability in soil and the plant's requirement.

Metal pollution has harmful effect on biological systems and does not undergo biodegradation. Toxic heavy metals such as Pb, Co, Cd can be differentiated from other pollutants, since they cannot be biodegraded but can be accumulated in living organisms, thus causing various diseases and disorders even in relatively lower concentrations. Heavy metals, with soil residence times of thousands of years, pose numerous health dangers to higher organisms. They are also known to have effect on plant growth, ground cover and have a negative impact on soil micro-flora.

It is well known that heavy metals cannot be chemically degraded and need to be physically removed or be transformed into nontoxic compounds (Bieby voijant tangahu *et al.*, 2011) [20].

The role of plants in Phytoremediation is by now recognized well and the relevant literature is reviewed under the important processes, which prevent heavy metals entry into food chain. The processes are:

i) Accumulation in plants
ii) Immobilization in soil and plants and
iii) Dissipation in the atmosphere.

Accumulation in plants

Phytoextraction: The contamination level in different crops growing in sewage irrigated area of Gujarat was assessed by Patel *et al.* (2006) [12] and observed that the cereals and grasses showed higher accumulation for most of the heavy metals. Further, Patel *et al*. (2004) [11] reported that Brinjal crop irrigated with fertilizer effluent showed exceptionally high amount of Fe (3360 ppm). Gupta *et al*. (2003) reported that the Cd concentration up to 10 µM proved to be inducing 100% germination of the seed. The heavy metal viz., Ni and Cr @ 30 ppm decreased dry matter yield of Tomato and Egg plants; and showed antagonistic effect with Cu, Mn and P (Khan and Khan, 2006) [5]. Khan and Moheman (2006) [5] reported that metal uptake by chilli decreased significantly as a result of increasing doses of Cd; and Ni showed a beneficial effect on metal uptake by sunflower. Reeves and Brooks (1983) [13] found 0.82% of Pb and 1.73% of Zn in dried leaves of the *T. rotundifolium sub spp. Cepaeifolium* grown on Pb and Zn contaminated mining areas. The *T. caerulescens* and *B. juncea* are the effective hyperaccumulator of Cd and Zn (Ebbs *et al*., 1997) [4] and Pb (Robinson *et al.*, 1998) [14]. Leita and De Nobilli, (1993) [7] reported that the total content of Cd in bush bean roots treated with 50 µM Cd (3016 µg/g dw) was more than 30 times to that of pea (87 µg/g DW). Similarly, Suthar *et al.* (2003) [19] also observed higher accumulation of Cd in leaves of different crops. McGrath *et al.* (2002) [8] reported the *T. caerulescens* accumulated 2000- 4300 µg/g Zn in dry weight shoot, which decreased to 500- 2200 µg/g in subsequent year. A hardy plant Brake fern is a extremely efficient in extracting Arsenic (As) from soil and translocate it into its above- ground biomass. Scented Geraniums accumulated significant levels of Cu, Cd, Pb, Ni and Zn from the soil (Saxena *et al*., 2000) [16].

The yield of maize increased significantly with increasing application of Pb up to 25 mg/ kg soil and decreased thereafter and Pb concentration in plants increased significantly with increase in concentration of Pb in soil. The medicinal plant spp. could accumulate heavy metals in high concentration against the concentration in soil (Kumar Nikhil, 2006) [10]. The addition of EDTA increased the plant uptake of Cd, Zn, Pb, Ni and Cu (Stanhope *et al.*, 2000) [18]. Datta *et al*. (2007) [2] indicated that DTPA extractable Cd increased from 0.11 to 6.17 mg/ kg with application of 10 mg Cd/ kg; and $CaCO_3$ @ 5% significantly reduced the DTPA- extractable Cd in soil and also reported that Cd content in plant was raised from 0.59 to 12.07 mg/kg in Cd treated pots. Zoya ghori *et al*. (2016) [22] reported that the hyper accumulators have the tendency to take up even nonessential elements by 100-fold greater than non-hyper accumulators. Because of their larger biomass, they can gather heavy metals using ion channels and metal transport proteins through roots and store them in the above-ground organs where they are either stored in vacuoles and cell walls or detoxified. More than 450–500 plant species have been identified as hyper accumulators including *Thalaspi* and *Arabidopsis* and members from families such as *Brassicaceae*, *Cyperaceae*, *Poaceae*, *Fabaceae*, and several others.

Rhizoflltration: Rhizoflltration is a type of phytoremediation, which refers to the approach of using hydroponically cultivated plant roots to remediate contaminated water through absorption, concentration, and precipitation of pollutants. It also filters through water and dirt. The contaminated water is either collected from a waste site or brought to the plants, or the plants are planted in the contaminated area, where the roots then take up the water and the contaminants dissolved in it. Rhizoflltration may be applicable to the treatment of surface water and groundwater, industrial and residential effluents, downwashes from power lines, storm waters, acid mine drainage, agricultural runoffs, diluted sledges', and radionuclide-contaminated solutions. Plants suitable for Rhizoflltration applications can efficiently remove toxic metals from a solution using rapid-growth root systems. Various terrestrial plant species have been found to effectively remove toxic metals such as Cu^{2+}, Cd^{2+}, Cr^{6+}, Ni^{2+}, Pb^{2+}, and Zn^{2+} from aqueous solutions (Dushenkov *et al.*, 1995) [3].

Effect of various soil amendments on bio- availability of Cd and Pb in rye grass and tobacco plants were studied by Mench *et al.* (1994) [9]. The effectiveness of lime, Thomas phosphorus basic slug and hydrated Manganese Oxide (HMO) were at par however; HMO application immobilized 3- 4 times less Cd and Pb to crops.

Dissipation in the atmosphere

Phyto-volatilization: The rate of Se volatilization by different plant spp. was strongly correlated with the plant tissue Se concentration (Terry *et al*. 2002) [21]. Singh *et al.* (1980) [17] reported that in the absence of sulphur, Se tends to accumulate in roots of Indian mustard.

Conventional heavy metal alleviation methods harm soil health. Induced Phytoextraction is the effective method when heavy metals load is low. *Thlaspi caerulescens* plant is capable of accumulating Zn and Cd in shoot up to 1% and 0.2%, respectively. Metal removal by *Brassica* spp. is found a potent hyper accumulator plant.

Additions of manganese oxide as amendment to soil lower the Cd and Pb uptake by ryegrass and tobacco. Brake fern can efficiently be grown on As-contaminated soils.

For the plants to effectively take up heavy metal contaminants, the contaminants need to be converted into water-soluble compounds. This technique is called induced phyto-extraction in which chelating agents are added in soil that desorb the toxic metals and allow easy uptake by roots. Most common chelates are ethylene diamine tetra acetate, ethylene diamine disuccinate, and other organic acids. However, they can increase toxicity of ground water and affect soil micro-fauna; therefore, environmental-friendly chelates need to be developed. Another strategy to detoxify soils is to create transgenic plants with increased hyper-accumulation activity against a particular metal. Hence, phyto-extraction can be a perfect technique for soil purification because of its minimal limitation (Zoya ghori *et al*., 2016) [22].

Phytoremediation is an important developing technology for removal of heavy metals from soil. It has the potential to be a low cost and to be applicable to large areas where other methods may be too expensive. Also, it is useful where the concentration of contaminants is too small for other methods to be effective or economically viable.

Future thrust

Plants have evolved a great diversity of genetic adaptations to handle the accumulated pollutants that occur in the environment. Growing and, in some cases, harvesting plants on a contaminated site as a remediation method is a passive technique that can be used to clean up sites with shallow, low to moderate levels of contamination. Phytoremediation can be used to clean up metals, pesticides, solvents, explosives, crude oil, poly-aromatic hydrocarbons, and landfill leachates. It can also be used for river basin management through the hydraulic control of contaminants. Phytoremediation has been studied extensively in research and small-scale demonstrations, but full-scale applications are currently limited to a small number of projects. Further research and development will lead to wider acceptance and use of Phytoremediation.

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