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Review

Removal of heavy metals from whole sphere by plants working as bioindicators- A review

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Pollution of the environment with toxic heavy metals has increased since increasing industrialization and human activities. These heavy metals have created a very difficult situation for the living being for a healthy life. A lot of studies have been done for the effects of heavy metals in environment. The aim of this paper is to find out most hyper accumulating plants for removal the heavy metals from the environment and to know the new techniques for more hyper accumulation in plants. We concluded that Kheya(for Co, Ni and Pb), Mango(*Mangifera indica* L.)(for Cu, Cd, Pb,), Anthyllis vulneraria, Thlaspi caerulescens, Iberis intermedia and Silene latifolia (for Zn, Cd and Tl) and Urtica dioica L (for Pb) are the most hyper accumulating plants in last decade. So if we plant such plants in the specific heavy metal polluted areas then they will be very affective for removal of heavy metals in those areas. This was also concluded that accumulating techniques specially plant engineering with gene transformation, hybridization, and mutagenesis may be a new emerging field of research for removal of heavy metals from atmosphere. Plants can be an new source for heavy metals.

Keywords: Bioindicators, accumulators, phytoremedation, heavy metals.

INTRODUCATION

Rapid urbanization, unregulated industrialization, growing transport, metal plating and agricultural activities have created a serious problem of heavy metals toxicity. (Donalas, and Edita, 2007; Culbard et al., 1983; Gibson et al., 1983; Haines et al., 1980; Parry et al., 1981; Raven et al., 1997; Young et al., 1973; Galloway, 1972; Chow, 1973; Bruland et al., 1974; Gibson et al., 1986; Harrison et al., 1981; Li et al., 2001; Thornton, 1991; Somashekar, 1984) The use of various transportation media, Smoke and unburnt fuel from faulty vehicles are spreading the level of heavy metals toxicity beyond the limit, which are toxic not only to human health, but also affect the plants on which they are deposited. So now this is priority to remove the heavy metals from environment. A lot of work has been done for removal of heavy metals by synthetic methods like, by activated carbons, by resin, by thin films and other volumetric techniques. But in all the methods one of the problem that is common, in all is the waste material and their chemically toxic nature. So we have a great need of such a natural process in which there should be no waste materials and toxicity after removal of heavy metals from the environment.

Plants play major contribution in purifying land, water and environmental air. To grow and complete the life, plants have great need not only of macronutrients (nitrogen, phosphorus, potassium, sulphur, and manganese) but also essential nutrients for ex- heavy metals (Shrestha, 2003) So plants may be a big solution for removal of the heavy metals from atmosphere. Heavy metals are taken up by plants from many pathways such as soil, water and atmosphere and from other modes. Heavy metals also pass through biological membranes. The major environmental factors that effects metal uptake by plants are soil acidity, heavy metal cation exchange capability and the concentration of macro and micro nutrients, which causes accumulation in plant tissue and changes plant community. The heavy metals limitation in trees or plants varies in different species. Plants known as hyper accumulators accumulate hundred or thousand times more heavy metals than normal plants. Hyper accumulator plants have a higher requirement of heavy metals in various organs of the plants. Heavy metals and the ratio of metals in various organs of plants species largely depend on plant morph-physiological characteristics. On the above basis the current classification divides all plants species into three groups.

1. The accumulator, that store metals mainly in the shoot high and low metal concentration in the soils.
2. The indicators, with plants metals concentration reflecting the metal content in the environment.
3. The excluder, with restricted transfer of heavy metals into the shoots whatever high are metal concentration in the environment and the roots.

So by using these accumulators and indicators we can remove the heavy metals from environment. Another fact that arises is that the plants having more accumulation properties can be used for removal of heavy metal (Verma et al., 2013) in the roadside environment in an affecting and natural way. A lot of work has been done on bioindicators especially for road side plants. Table 1. shows the last decade research on bioindicators and accumulators.

Process of heavy metals uptake, translocation and accumulation

Uptake of heavy metals

The major environmental factors that affect metal uptake by plants are soil acidity, its cation exchange capacity, the content of organic and lime and the concentration of macro and micro nutrients (European Commission Dg, J. Env. NEWS Alert Service, 2007.) Even this to grow and complete the life, plants needs not only macronutrients (nitrogen phosphorus, potassium, sulphur and magnesium) but also essential nutrients such as iron, zinc, nickel, copper and lead (toxic metals). So plants take up toxic metals too. Many toxic metals such as zinc, manganese, nickel and copper are essential micronutrients.

Some heavy metals are nonessential element to plants hence they do not posses specific mechanisms for its uptake therefore the uptake of such type of heavy metal are carried through carriers used for the uptake of essential metals for plants metabolism (Cervantes, 2001; Wallaceet al., 1976). Uptake capacity of heavy metal by plants also depends upon the oxidation and valance state of the metal. Wallace et al., (1976), have found that plants accumulate more chromium (VI) than chromium (III)

It has been seen that the maximum quantity of elements contaminant was always contained in roots and a minimum in the plant's leaves and reproductive organs. The reason of high accumulation in roots of the plants could be because heavy metal are immobilized in the vacuoles of the root cells, thus rendering it less toxic, which may be a natural toxicity response of the plant (Zayed et al., 1998.)

Translocation

The movement of metals from the root to shoot is called translocation. Translocation is primarily controlled by two processes. First is root pressure and second one is leaf transpiration. Following translocation to leaves metal can reabsorbed from leaf cells. This rate of long distance metal transport is different in various plants species. Heavy metals can migrate with soil. Some of them accumulate in it and often disturb by lowering the rate of transporting metals, the excluder plants can alleviate their toxicity.

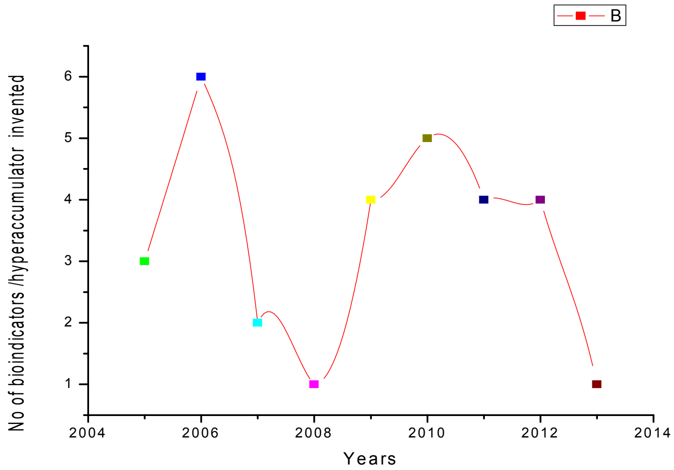
Hyperaccumulation

Hyper accumulation can be understood by knowing the term phytoremediation. The term phytoremediation ("phyto" means plant and the latin suffix remedial means to clean or restore) refers to a diverse collection of plant based technologies that use either naturally occurring or genetically engineered, plant to clean contaminated environment. (Chunningham et al., 1997. Flathman et al., 1998) Some plants which grow on metalloferous soils have developed the ability to accumulate massive amount of indigenous metals in their tissue without symptoms of toxicity. (Reeves and Brooks, 1983; Baker et al., 1989; Baker et al., 1991; Entry et al., 1999) These types of plants are known as hyperaccumulator and the process is called hyperaccumulation. Several comprehensive reviews have written, summarizing many important aspects of this novel plant based technology which tells that plants species vary in their capacity to accumulate heavy metals. (Salt et al., 1995; Salt et al., 1998; Chaney, 1997; Raskin et al., 1997; Chaudhry, 1998; Meagher, 2000; Navari-Izzo and Quartacci, 2001; Lasat, 2002; McGrath et al., 2002; McGrath and Zhao, 2003; Mc Intyre, 2003; Garbisu and Alkorta 2001; Prasad and Freitas, 2003; Alkorta et al., 2004; Ghosh and Singh, 2005; Pilon-Smits et al., 1999.) Thus we can say that hyperaccumulation is a big factor for the uptake of heavy metals in plants. Preliminary trials with Ni and Zn hyper accumulator plants from Brassicaceae family were successful in partially removing heavy metals from soils contaminated by long-term application of heavy metal containing sludge (Brown et al., 1994; Brown et al., 1995).

Table 1. A research profile of plant species working as an accumulators and bio-indicators.

Name of plant	Bioindicator / Accumulator	References
neem (Azadirachta indica), kaner (Nerium oleander L.), Ashok (Saraca indica L.) and imli (Tamarindus indica)	Bioindicators	Verma D.K. et al (2013)
Azardiractha indica (Dongoyaro)	Bioindicator	Majolagbe O. et al. (2010),
Ficus vopelli (Odan-abebe) and *Terminalia catapa* (Indian almond or fruit tree)	Biomonitor	Majolagbe O. et al. (2010),
Cercis siliquastrum L. and subsp. siliquastrum	Biomonitor	Yasar U. et. al. (2010),
(*Pinus Eldarica Medw*.) needles	Biomonitors	Kord B. et. al. (2010),
The bark of *P. brutia*	Biomonitors	Dogan, Y. et. al. (2010),
soybean (Glycene max)	Accumulator for chromium	Jayakumar K. and Jaleed, C. A. et al. (2009)
Rhododendron Pulchrum	Bioindicator	Suzuki K. et al. (2009),
Corylus abellans, Alopecurus myosurm, Helleporus orientalis, Glechoma hederacea, Calamintha nepeta and *Urtica dioca*	Bioindicator	Huseyinova R. and Kozhevni KAD. (2009),
Prosopis juliflora swartz, Abutilon indicum (L.) Sweet and *Senna holosericea (Fresen) Greuter*	Accumulator	Rehman SAU. et. al. (2008),
Pinus brutia Ten (Turkish red pine)	Biomonitor	Dogan Y. et. al. (2007),
grass (*Panicum maximum*)	Bioindicator	Akinola MO. and Adedeji O.A. (2007)
Fraxinus excelsior	Biomonitor	Aksoy A. and Deminrezen D. (2006),
Rosa rugosa	Biomonitor	Calzoni GL. et al. (2006),
Raphanus sativus L. and Spinacia olerac L.	Accumulator	Pandey SN. (2006),
Hyophila inroluta (Hook)	Accumulator	Deora GS. et al. (2006),
Kheya	Hyperaccumulator for cobalt, nickel and lead	Arby AME. and Elborkiney MM. (2006),
Axodium and Italian cypress trees	Higher accumulator for both nickel and lead.	Arby AME. and Elborkiney M M. (2006),
Cladophora fracta	Accumulator	Lamai C. et al. (2005).
Bacopa monnieri	Accumulator	Shukla OP. et al. (2005)
scpariadulcis Linn	Bioindicator	Gundi G. et al. (2005),
Robinia pseudoacacia	Bioindicator	Samecka A. et al. (2009),
faba beans	Accumulator for Fe, Zn, Mn, Ni.	Rabie M H. et al. (1992),
wheat and *sprghum.*	Accumulator for Fe and Zn	Rabie MH. et al. (1992),
Mango (*Mangifera indica* L.)	Most hyperaccumulator for Cu, Cd and Pb	Sahar A. El-Khawas (2011)
Pyxine cocoes and *Phaeophyscia hispidula*,	Biomonitor	Bajpai R. et al. (2011)
Anthyllis vulneraria, Thlaspi caerulescens, Iberis intermedia and Silene latifolia	hyper accumulator for Zn, Cd and Tl	Escarré J. et al. (2011)
Azadiractha indica , Psidium guajava	Accumulators for Zn, Cd and Pb	Ljeoma L.et al. (2011)
Taraxacum officinale L. and *Trifolium pratense L*	Accumulators for Cu	Malizia D. et al. (2012)
Urtica dioica L	Accumulators for Pb	Malizia D. et al. (2012)
Laurus nobilis L	Biomonitor	Yasar U. et al. (2012)
Casuarina equisetifolia needles	Biomonitor	Aissa L. et al. (2012)

Table 1.1- A research profile of plant species working as an accumulators and bioindicators.



Figutre 1. No of inventions in bio-indicators/ hyper accumulators year wise

Phytoremediation by plants

Scientist are inventing new technique on day by day for removal of the heavy metal but because of the very low cost of this technique, phytoremediation have become the most popular and interesting research area for the researchers. Figure 1. clears that from the last decade phytoremediation have been a very interesting subject for the researchers.

Phytoremediation can be up to 1000-fold cheaper than conventional remediation methods such as excavation and reburial. Moreover, it offers permanent in situ remediation rather than simply moving the pollution to a different site. Plant engineering has provided a tremendous research for improving accumulating properties. Some of the ways for improving are as following:

- By introducing genes responsible for accumulation and resistance from wild slow growing plants to fast growing high biomass plant species.
- In the absence of known 'phytoremediation' genes, this may be accomplished via somatic and sexual hybridization,
- Mutagenesis of selected high biomass plant species may also produce improved phytoremediating cultivars.

Meager and colleagues set out a new approach to introduce bacterial genes that convert methylmercury to volatile elemental mercury in plants (Bizly et al., 1999; Bizly et al., in press). The same MerA and MerB genes were used to create mercury-volatilizing plants in other species. Enhanced mercury tolerance has already been found in transgenic Mer A and Mer B tobacco and yellow poplar (Rugh et al., 1998; Bizly et al., in press).

Chemistry / Mechanishm of phtoremediation

There are several ways by which plants clean up contaminated sites. The uptake of contaminates in plants occurs primarily though the root system and leaves system in which the principal mechanisms for preventing toxicity are found. The root system provides an enormous surface area that absorbs and accumulates the water and nutrients essential for growth along with other non essential contaminants. Plant roots changes the soil-root interface as they release the organic and inorganic exudates in the rhizoshpere, which affect the aggregation, stability of the contaminants. Root exudates do not remains constant but it varies and depends on the soil characteristics. The second system is the leaves system in which a lot of pores are presents, when heavy metals particles deposit on the leaves then these pores absolve some part of these heavy metals and clean the environment.

Phytoremediation processes /applications of bioindicators and hyperaccumulators

Depending on the underlying processes, applicability, and type of contaminant, phyto-remediation can be broadly categorised as:

1. Phytodegradation or phyto- transformation: This is the process by which contaminants are broken-down by the compounds (such as enzymes) produced by the plants. Thus complex organic pollutants are degraded and incorporated into the plant tissues for growing the plant faster. In this process some enzymes break down and convert ammunition waste and other degrade chlorinated solvents and other herbicides.

2. Phytostimulation or rhizodegradation: in this process organic contaminants in the rhizosphere are broken-down through microbial activity which is enhanced by plants root. This process is much slower than phytodegradation. Yeast, fungi or bacterial are the micro organisms which digest these organic substances like fuel or solvent.

3. Phytovolatilisation: In this process contaminants are uptaken and transpirated by plants and released modified form of the contaminant from the plant to the atmosphere. Some of the contaminants passes though the leaves of the plants and evaporated.

4. phytoextraction or phytoaccumulation: this process refers to the uptake and translocation (transfer of metal from root to shoot) of metals in the plant. In this process hyperaccumulators plants are planted at particular site based on the type of metals present on that site. After the growth period of the plants, they are harvested or incinerated. This process is repeated until we do not get good quality of soil. Nickel, zinc and copper are the best metals for removal of by this process because more than 300 plants uptake and relocate these metals.

5. Rhizofiltration: This process is similar to the phytoextraction but in this process plants are used for cleaning contaminated water. The plants are planted where the roots take up the water and contaminates along with it. For this first the plants are raised in greenhouse with their roots in water, when a large root has been produced, then the plants are planted in the contaminated area where the roots take up the contaminants.

6. *Phytostabilisation*: in this process such plants species are used which root could stop or reduces the mobility of contaminant and prevents migration to the ground water and bioavailability of metal in to the food chain by absorption and adsorption. Thus this technique is used to cover the vegetation at sites where natural vegetation fails to survives due to high metals concentration in surface soil.

Limitation and selection of plant for phyremedation

The selection process for the plant for the phytoremedation is a most important and difficult process. The selection of the plant is also done on basis of climate condition and seasonal cycle. Some important criteria (Sharma, 2011) in selection of the plant species for the phytoremedation are:

- The level of tolerance with respect to known metal to exist at the site.
- The level of adequate accumulation, translocation, uptake and potential of metals.
- High growth rate and biomass yield.
- Tolerance to water logging and extreme drought conditions.
- Availability, habitat preference e.g., terrestrial, aquatic, semi-aquatic etc.
- Tolerance to high pH and salinity.
- Root characteristic and depth of the root zone.

Although phytoremedation is the best method for purification of heavy metals from whole sphere but there are several limitation (Sharma, 2011) in this technique. It is generally slower than most of the other techniques like chemical and physical treatment. Metal should be bioavailable form to plant. If metal is tightly bound to the organic portion of the soil, some time it may not be available to plant. If the metal is water soluble it may pass though the root without accumulation.

Future work and reseach

Review reveals that the accumulation of the plants by phytoremedation is most important technique for removal of heavy metals from the whole sphere, but because of several limitations, there is an intensive need of doing research (Sharma, 2011) on plant species and soil condition. In depth research study is warranted to find out which plant is maximum resistant (Sharma, 2011) and best adapted in particular metallic environment or region. In-situ toxicity text could be beneficial for initial identification of particular species.

CONCLUSIONS

Heavy metals are the most useful and toxic metals, i.e spreading all over the sphere of the earth. So for a healthy vital life, this is priority now to remove the heavy metals from our environment. Trees as an accumulator and bioindicators can play a big role in cleaning environment in an affecting way. The most accumulating trees should be planted on road side so that they could achieve most of the heavy metals exiting through roadways vehicles. Every accumulating or bioindicating tree has a specific level of accumulating and bioindicating properties for fixed heavy metals. So we should plant only those trees which are necessary for that environment, like Anthyllis vulneraria, Thlaspi caerulescens, Iberis intermedia and Silene latifolia tree are most hyper accumulating plant for Zn, Cd and Tl, so they should be planted in that environment where these metals are present. Kheya(for Co, Ni and Pb), Mango (*Mangifera indica* L.) (for Cu, Cd, Pb,), Anthyllis vulneraria, Thlaspi caerulescens, Iberis intermedia and Silene latifolia (for Zn, Cd and Tl) and Urtica dioica L (for Pb) have been found the most hyper accumulating plants in last decade. These plants can be used as a heavy metal removal species in the roadside or polluted sites. These most hyper accumulating species can also be the source of different metals which can be used for different applications.

Although phytoremediation is a good process for removing of heavy metals, but there are also some limitation so if we improve these limitation then it can be most useful method. A lot of research is required to do in this field. Accumulating techniques specially plant engineering with gene transformation, hybridization, and mutagenesis may be a new emerging field of research for removal of heavy metals from our atmosphere.

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