PHYTOREMEDIATION OF HEAVY METAL CONTAMINATED SOILS USING VARIOUS FLOWER AND ORNAMENTALS

ABSTRACT: Soil contamination has become a serious problem in many industrialized and developing countries. Indiscriminate dumping of urban and industrial effluents along with solid waste often lead to toxic accumulation of heavy metal ions which not only impair soil productivity but also cause health hazards by entering into food chain *via* soil-plant-animal/human route. With rapid urbanization and industrialization, large quantities of industrial effluents get mixed with sewage and river water (Raj *et al*., 2006). Irrigating crop fields with such contaminated sewage water is being increasingly adopted by marginal farmers due to scarcity of irrigation water. It also inadvertently leads to addition of large quantity of heavy metals to the agro ecosystem (Kumar and Dhingra, 2005). Plants with abilities to hyperaccumulate, accumulate, exclude and indicate heavy metals are important in environmental remediation. Most phytoremediation studies are aimed at inorganic pollutants through different approaches defined as phytoextraction (the used of metal accumulating plants to transport and concentrate metals from the soil to roots and above ground biomass), rhizofiltration (the use of plant roots to absorb, precipitate, and concentrate toxic metals from polluted effluents), and phytostabilization (the use of plants to reduce the mobility of metals)

Key Words: Soil contamination, Heavy metal ions, Phytoremediation, Rhizofiltration, Phytostabilization

INTRODUCTION: Phytoremediation is defined by Cunningham and Lee (1995) as “the use of green plants to remove, contain, or render harmless environmental contaminants”. “This applies to all plant-influenced biological, microbial, chemical and physical process that contribute to the remediation of contaminated site. It is also known as green technology and proper implementation make it eco-friendly and aesthetically pleasing to the public. Phytoremediation does not require any expensive equipment or highly-specialized personnel, thus, it is relatively easy to implement. It is capable of permanently treating a wide range of contaminants in a wide range of environments. Thus, phytoremediation of contaminated environment offers an environmentally friendly, cost effective, and carbon neutral approach for the cleanup of toxic pollutants in the environment. Remediation methods available for reducing the harmful effects at heavy metal contaminated sites include chemical, physical and biological techniques. These can be grouped into two categories *i.e.* ex-situ and in-situ methods. The conventional ex-situ methods applied for remediating the polluted soils relies on excavation, detoxification and/or destruction of contaminant physically or chemically, as a result the contaminant undergo stabilisation, solidification, immobilisation, incineration or destruction” (Ghosh and Singh, 2005).

Role of Flowers and Ornamentals in Phytoremediation:

Samuel et.al (2021) Studied on “irrigation of the *Heliconia psittacorum* with 10 ppm each of the heavy metals (mercury (Hg), arsenic (As), cadmium (Cd) and lead (Pb) and metalloid. The roots and shoots of the plant were analysed for the number of heavy metals and metalloid absorbed by the plant after specific periods. There was high bio-absorption rate of As, Hg and Cd by *Heliconia psittacorum* when each of the heavy metals/metalloids were the only contaminant in water as well as when all the four contaminants were together in the water. This means that the macrophyte can remediate As, Hg and Cd in soil and water”. Gour et. al (2018) analyzed “accumulations of the heavy metals were after 30, 60 and 90 days in flowers, leaves, stem and roots by Atomic Absorption Spectrophotometer and reported that Catharanthus roseus, as non-edible, shrub species, aesthetically pleasant with beautiful flowers is used for metal uptake successfully. The results showed that metals Iron (Fe), Nickel (Ni), Cadmium (Cd) and Copper (Cu) are highly accumulated by the roots than stem and leaves. It was concluded that the plant species was a good accumulator of metals”. Mateos et.al (2018) concluded that “*Jatropha curcas* L. was found to absorb great amounts of Fe (>3000 mg kg−1 plant) as well as notable amounts of Pb, Zn, Cu, Cr and Ni, and traces of As. Other metals with lower initial concentrations such as Cd, Hg and Sn were completely removed from soils deals with removal of heavy metals from marginal soil mixtures from the Cobre Las Cruces and Aznalcóllar mining areas containing high concentrations of metals (Cr, Fe, Ni, Cu, Zn, Cd, Hg, Pb and As) by means of phytoremediation using *Jatropha curcas* L”. Abbaslou, H. and Bakhtiari, S. (2017) have been grown “Eucalyptus and Ailanthus trees in a soil sample, contaminated with heavy metal iron ore mining and collected from southern Iran. Amounts of Cd, Pb, Zn, Cu, and Mn have initially been at toxic levels which declined after cultivation. Fibrous clay minerals have been added to soils as a natural adsorbent to adsorb heavy metals like Pb, Cd, Zn, and Mn. Accumulation of the elements in the roots and shoots has been in the following order: Cu>Zn>Mn>Cd>Pb>Fe. The organ metal concentrations have not statistically translocated from roots to shoots of plants, except for Zn and Cu whose concentrations have been significantly higher in roots. Eucalyptus is well capable of extracting elements from contaminated soils, compared to Ailanthus, particularly in case of Cu and Cd". Rungruang and Babel (2016) concluded that "total biomass of guinea grass was around nine times higher than marigold for Cd treatments of 50 and 100mg/Kg which resulted in it showing more Cd uptake than marigold. The maximum cadmium uptake, bioconcentration factor, translocation factor occurred at Cd treatment of 100 mg/Kg. Marigold takes fewer years than guinea grass when soil pH is higher than five and guinea grass takes less time when soil pH is five". Mani *et al*. (2014) reported that "Lead (Pb) applied at 50 mg Kg-1 caused reduced plant height, root length and dry biomass. Lead (Pb) concentration in tissue followed the order root>shoot>flower. Chrysanthemum can be grown in Lead (Pb) contaminated soils along with application of elemental sulphur and vermicompost which will boost the photosynthetic pigments which were decreased due to Lead application". While working with *Catharanthus roseus* Ahmad *et al*. (2014) concluded that "about 38 percent of chromium was absorbed through roots and about 22 per cent was accumulated in leaves. *C. roseus* was found to be resistant to chromium and showed tolerance up to 375 µg/g soil. It was also found that there was decreased biomass and alkaloid content due to chromium contamination. Some ornamental plants such as *Chlorophytum comosum* have exhibited high tolerance to more than one type of pollutant. the dry weight and height of *Calendula officinalis* was found to increase to different extents with an increase in the soil Cd concentration". Similar results were also found in *Chlorophytum comosum*: the lengths of the roots and aboveground parts reached their maximal value at a Cd concentration of 5 mg/kg dry weight soil, and the dry weight of the roots reached its peak value at a Cd concentration of 20 mg/kg dry weight soil. Italian ryegrass (*Lolium multiflorum*) and white clover (*Trifolium repens*), two ornamental herb species, had better tolerance to Cd based on the median inhibition concentration values of seed germination and root and shoot elongation in hydroponics by Liu *et al* (2013). Pal *et al*. (2013) concluded that the uptake of Cd and Ni increased with contents in soils. Floricultural plants have a higher translocation when compared to vegetable and cereal crops with maximum accumulation in roots.

Among the floricultural plants used for the experiment *i.e.* marigold, hibiscus, jasmine, rose, bela (*Jasminum sambac*), highest Cd was found in roots of Bela followed by shoots of marigold and soils of rose. Highest Ni was seen in roots and shoot of marigold and soils of rose. The results indicate that among the various floricultural plants used marigold was ideal for phytoremediation of Cd and Ni. Thamayanthi *et al*. (2013) studied Lead phytoremediation using marigold and zinnia and concluded that zinnia had the ability to extract an approximately greater amount of Lead than marigold, zinnia also showed maximum uptake of Lead. Lead accumulation was higher in all plants on 60th day. Ahmadi *et al*. (2013) reported that, the younger plants of *Pelargonium roseum* had more potential to uptake and concentrate Pb, Cd, Co, Ni, and Cr. The uptake of heavy metals was significantly affected by the plant accumulation and soil pH. Subhashini *et al*. (2013) revealed that, plants with bio concentration factor and translocation factor more than one have potential to be used in phytoextraction of cadmium. The plants *Acalypha indica, Abutilon indicum, Physalis minima, Cleome viscosa, Catharanthus roseus, Ruellia tuberose, Canna indica, Perotis indica, Echinocloa colona, Cyperus rotundus* were all suitable for phytostabilization *and Catharanthus roseus* can be used for phytoextraction. According to Ramana *et al*. (2013) Dahlia recorded the highest concentration of Chromium and Calendula the least. Chromium beyond 10 ppm was toxic to the plants resulting in drastic reduction in plant growth and at 25 ppm caused mortality of plants. Chromium at 10 ppm inhibited flowering in Calendula and dahlia. Calendula can be used for phytoremediation of soils with low level of Cr (up to 10 ppm).Whereas in rose a higher concentration of chromium was found in roots than in shoot of the plant. Reed *et al*. (2013) investigated arsenic phytoremediation with various ornamental crops and found that only small amount of arsenic was found in iris root and shoot. Tithonia and coreopsis were most sensitive to arsenic exposure but had higher uptake ratio even in low arsenic concentrations. Marigold and sunflower had translocation factor near one and higher uptake ratio and were therefore better suited for phytoremediation. Ramana *et al*. (2012) conducted an experiment on three varieties of tuberose *i.e.* Prajwal, Mexican single, Shringar for phytoremediation of cadmium and concluded that the variety Prajwal recorded highest Cd content in shoot and uptake followed by Mexican single and Shringar. Fraction of total cadmium removal percentage was higher than mustard which was considered as a hyperaccumulator. Similarly, Chatterjee *et al*. (2012) studied elements in sunflower, marigold and cock’s comb of contaminated areas and observed general accumulation patterns for different metals being root>leaf>stem>flower. Highest Cr was recorded in roots of cocks comb followed by roots of sunflower and marigold. Maximum Cr accumulation was seen in leaves of cock's comb and minimum in flowers of sunflower. Lead content in roots of sunflower were highest followed by marigold and cock's comb. The concentration of Lead in leaf of sunflower and cocks comb was almost similar. Highest concentration of lead was found in flower of marigold and lowest in flower of cock's comb. The biomass produced by cock's comb was highest followed by sunflower and marigold which indicates to cock's comb being best for phytoremediation. Borghei *et al*. (2011) evaluated "the potential of *Calendula alata* for phytoremediation of stable Cesium and Lead from solutions and reported that it was more suitable for Lead phytoremediation than Cesium". "Irrigation of flower crops with tannery effluent water resulted in considerable amount of Cr accumulation in J.sambac, J.grandiflorum, P.tuberosa and N.oleander was examined. French Marigold is a hyper-accumulator of Cd metal (45 to 66 mg kg^{-1} in shoots and 65 to113 mg kg^{-1} in roots) without showing any toxic symptoms in the pot experiment" conducted by Lai et al (2010). Lal *et al.* (2008a) evaluated "the production potential and cadmium removal by marigold, chrysanthemum and gladiolus. The total cadmium removal was maximum with chrysanthemum followed by gladiolus and minimum with marigold. At higher applied cadmium levels *i.e.* > 7.9 mg g-1 the reduction in yield was maximum in marigold followed by chrysanthemum and gladiolus. Dry matter produced per unit area followed the order: chrysanthemum > gladiolus > marigold. The accumulation of cadmium in different plant parts followed the order: leaves>flower>stem in marigold and chrysanthemum. Gladiolus spikes accumulated the highest Cd followed by marigold and chrysanthemum. The cadmium content in gladiolus followed the trend: corm (64 per cent of total uptake) > spike > straw. Gladiolus accumulated more Cd at higher levels". An experiment was conducted by Ramana *et al*. (2008) "to study the tolerance and bioaccumulation of lead by gladiolus. It was revealed that the supply of Cd beyond 50 mg kg-1 concentration significantly decreased the total dry weight, concentration of chlorophyll pigments, the length of the spike, size of the florets and the number of florets/spike. However, the application of Pb did not show any inhibitory effect on the plant growth. The plant accumulated larger portion of the Cd (50 per cent) and Pb (82 per cent) in the roots +corms followed by stem, leaf and spike. The results of the study suggested that gladiolus a floriculture plant could be successfully grown in soils contaminated with low levels of Cd and low to moderately high level of Pb”. Liu *et al*. (2008) stated that the concentration of Cd in roots and shoot increased with increasing Cd concentration in the soil for both *Calendula officinalis* and *Althea rosea.* Leaf was most effective in accumulating Cd in *C. officinalis.* The roots of *Althea rosea* showed more prominent increasing Cd accumulation with increasing Cd content than other plant parts. Tiwari *et al*. (2008) conducted studies on phytoremediation efficiency of *Portulaca tuberose* and *Portulaca oleracea* and concluded that roots contain higher amount of metals (Fe, Zn, Cd, Cr,) than shoot. Flowers showed the least accumulation of metals. In *P. tuberose* in both roots and shoot, Cr showed highest accumulation followed by Fe whereas in *P. oleracea* Cr slowed highest accumulation in roots followed by iron while in shoots Fe accumulation was higher than Cr. Chintakovid *et al*. (2007) conducted field experiment studies on marigold for arsenic phytoremediation and concluded that leaves accumulated maximum arsenic and flowers minimum. Indian Marigold grown on contaminated soils of 50 and 500 mg kg^{-1} grapheme oxide promotes growth and 500 mg kg^{-1} of zero-valent iron nanoparticles is harmful to plants [29]. Among the ornamental plants studied for phytoremediation potential (Jasminum sambac, J.grandiflorum, Polianthes tuberosa and Nerium oleander), Jasminum sp. was found to be shown high degree of tolerance to Cr contaminated soils was found by Mahimairaja *et al.* (2005). In another experiment on tannery effluent irrigation Anandhkumar (1998) examined “the level of Cr accumulation in flower plants, *viz.*, *Jasminum sambac*, (Gundumalli), *Jasmium grandiflorum* (Jathimalli), *Polyanthus tuberose* (Tuberose) and *Nerium oleander* (Nerium) and found that a considerable amount of Cr was accumulated in flower crops due to irrigation with tannery effluent”. Ramasamy (1997) observed that “*Jasminum auriculatum* was relatively tolerant up to 1000 μg g^{-1} Cr in soil than *Crossandra infundibuliformis* and *Jasminum sambac*, which were found very sensitive at this concentration”.

CONCLUSION:

Further, landscape plants need to be screened and their phytoremediation capacity to be worked out for use against different heavy metals like mercury, arsenic, chromium, etc. Studies are required for the assessment of microbial role in phytoremediation and its role in plant health.

The use of other decontaminants like various organic acids, microbes and their suitability towards specific plants needs to be explored.

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