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Phytoremediation of A Polluted Environment with Heavy Metals

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Abstract: Environmental pollutants are currently one of the world's most pressing problems, causing catastrophic and irreparable damage to the natural world and human society, with water, air, and soil pollution accounting for over 40% of all deaths worldwide. Soil is one of humanity's most valuable natural resources. It is extremely important for agricultural sustainability and society's civilization. Plant-mediated decontamination is known as phytoremediation. Using phytoextraction technique, metals are removed from plant roots and then translocated to shoots. Mining, smelting, electroplating, energy and gas making, strength transmission, vast agriculture, sludge disposal, and melting activities are all human sports that contribute significantly to heavy metal pollution. The Hyper Accumulator can collect higher concentrations of heavy metals in aboveground quantities. Plants are used in phytoremediation to clean up contaminated surroundings. Heavy metals, pesticides, explosives, and oil are just a few examples of pollution that plants can help reduce. Because certain plant species have a very low risk of food chain infection, assist to improve the environment, and have a lot of monetary value, using attractive flowers as part of a phytoremediation strategy has a variety of practical consequences.

Keywords: Phytoremediation, Heavy metal, Phytoextraction, Hyperaccumulator and Non hyperaccumulator

1 Introduction

Soil is one of humanity's most important and precious natural resources. It is fairly dependent on agricultural sustainability and society's civilisation (Lone et al., 2008). However, heavy metal pollution of soil is a major threat to humanity and a global concern. Many parts of the world, including Central and Eastern Europe (roughly 1.7 million web sites), the United States (0.6 million brownfields), and developing countries like China (1/6 of cultivated land, or >20 million hectare), India, Pakistan, and Bangladesh, are struggling to find a solution to heavymetal contamination in soil, despite the fact that the problem varies in location and severity (Yao et al., 2012; Sharma and Pandey, 2014).

The word phytoremediation is derived from the Greek prefix "phyto," which means "plant," and the suffix "remedium," which means "to clean (or) restore" (Cunningham et.al.,1996).

Phytoremediation is a decontamination process involving plants. Plant life, such as grasses, bushes, and trees, work with microorganisms to clean up the environment (soil, water, and air) by degrading, accumulating, and stabilising toxins (Gomes, 2012; Rajkumar et al., 2012; Cameselle et al., 2019). Phytoremediation is a collection of four plant-based technologies for the remediation of metal-polluted soil, sediment, or water, each with its own mode of action. Phytoextraction is a process in which plants take metals from the soil and transport them to harvestable branches, where they concentrate. Rhizofiltration is the process of cleaning diverse aquatic environments with plants. Plants are employed to stabilise rather than clean contaminated soil in phytostabilization. Phytovolatalization is the process of using plants to harvest metals from soil and then releasing them into the atmosphere via volatilization.

Hyperaccumulators are plant species that can accumulate extremely high quantities of heavy metals in their aboveground portions without showing indications of phytotoxicity (Rascio and Navari-Izzo, 2011; van der Ent et al., 2013). Under the same conditions, a naturally occurring heavy metal hyperaccumulator can accumulate metals 100 times more than non-hyperaccumulating species (Rascio and Navari-Izzo, 2011). The definition of hyperaccumulator must strictly adhere to the following criteria: (i) the shoot-to-root ratio of heavy metal concentration is greater than 1, indicating an efficient ability to transport metals from roots to shoots (McGrath and Zhao, 2003; Marques et al., 2009); (ii) the shoot-to-soil ratio of heavy metal concentration is greater than 1, indicating a higher capability to take up heavy metals from soil (McGrath and Zhao, 2003); and (iii) The metal content in the shoot exceeds 10 mg/kg for Hg, 100 mg/kg for Cd and Se, 1,000 mg/kg for Co, Cu, Cr, Ni, and Pb, and 10,000 mg/kg for Zn and Mn (Baker and Brooks, 1989).

1.1 PHYTOEXTRACTION

This approach entails the extraction of metals by plant roots and their subsequent transport to shoots. To get rid of the toxins in the soil, the roots and shoots are eventually plucked. The ability of the Chinese brake fern, P. vittata, to hyperaccumulate arsenic has been determined by University of Florida researchers. The ferns were planted at a wooden-keeping site with soil contaminated with between 18.8 and 1,603 parts per million arsenics, and their tissues accumulated between 3,280 and 4,980 parts per million arsenics, according to a field test (Ma et al., 2001). The development of plants–hyperaccumulators capable of absorbing heavy metals in 50m 500 times more content material than regular plants has accelerated the development of phytoextraction technologies (Baker andBrooks,1989).

Cd: Thlaspi caerulescens tolerated 63.2 M Cd in hydroponic solution for 21 days without showing any signs of chlorosis, but became badly harmed at 200 M (22 mg/L) (Brown et al. 1995).

Thlaspi caerulescens survived 3,160 M Zn in hydroponic solution for 21 days without showing signs of chlorosis, but became seriously affected at 10,000 M (650 mg/L) (Brown et al. 1995). Hyperaccumulator plants are found in the plant families Brassicaceae, Euphorbiaceae, Asteraceae, Lamiaceae, and Scrophulariaceae (Baker 1995). Trifolium alexandrinum was used by Ali et al. (2012) to investigate the phytoextraction of four heavy metals (Cd, Pb, Cu, and Zn) from simulated polluted soil. T. alexandrinum is a plant that belongs to the Fabaceae family. It is grown as a feed crop for cattle. It was chosen because it grows quickly, is resistant to pollution, generates a lot of biomasses, and provides multiple harvests in a single growth length.

1.2 HYPERACCUMULATOR

These plants are known as hyperaccumulators because they may accumulate larger amounts of heavy metals in their aboveground portions. Brooks et al. (1977) developed the term hyperaccumulator to characterise plants with more than 0.1 % nickel (Ni) in their dried leaves. Since then, threshold values have been established for other metals, including zinc (Zn), lead (Pb), cadmium (Cd), copper (Cu), chromium (Cr), iron (Fe), manganese (Mn), and many more. (Brooks 1998).

They can absorb extremely large levels of one or more metals without experiencing any phytotoxic effects. They grow slowly and produce small amounts of biomass each year. BCF and TF values of >1 are required for such plants. Weeds, marsh plants, and a few local flora are examples of hyperaccumulator plants. Metal accumulation is a natural defence mechanism for hyperaccumulators against herbivores and pathogens.

The term hyperaccumulator refers to plants that accumulate more than 1,000 mg/kg of Cu, Co, Cr, Ni, or Pb, more than 10,000 mg/kg of Mn or Zn, or more than 100 mg/kg of Cd in their aerial components (Baker and Brooks 1989). The vegetation for phytoextraction of heavy metals from any polluted site must have the following characteristics: I tolerance of high steel ranges, (ii) accumulation of relatively excessive levels of metal in their aboveground tissues, (iii) rapid growth rate, (iv) moderately high biomass in the discipline, and (v) a profuse root system. Lorestani et al. (2011) investigated the phytoextraction and phytostabilization potentials of plants growing in a copper mine's heavy metallic-infected soil. They discovered that none of the Euphorbia macroclada was the most effective in phytostabilization of Cu and Fe, Ziziphora clinopodioides, Cousinia sp., and Chenopodium botrys were the most suitable for phytostabilization of Zn, and Chondrila juncea and Stipa barbata had potentials for phytoextraction.

1.3 NONACCUMULATOR

Metal hyperaccumulator plants have the potential to be effective in soil cleanup since they can absorb large amounts of metals from diseased soils, sediments, and water. However, their slow growth and limited yearly biomass production limit their phytoextraction capacities. Locating non accumulator vegetation with both excessive biomass plant life (crops) and fast-growing trees that can be easily cultivated using installed procedures is a possible solution (Ghosh and Singh2005,). When taken up from infected soil, they keep the majority of heavy metals in their root cells, detoxifying them via chelation inside the cytoplasm or storing them in vacuoles. Crop plants and trees, in particular, are nonaccumulator plants. Metals are only found in a small percentage of shoots, which contain the cytoplasm and chloroplast of mesophylls. Steel is found in greater quantities in the roots of nonaccumulating populations.

2 TOXICITY OF METAL

All plants can accumulate "essential" metals (Ca, Co, Cu, Fe, K, Mg, Mn, Mo, Na, Ni, Se, V, and Zn) from the soil solution. For growth and development, plants require varied concentrations. This ability also permits plants to collect "non-essential" metals such as Al, As, Au, Cd, Cr, Hg, Pb, Pd, Pt, Sb, Te, Tl, and U, which have no recognized biological role (Djingova and Kuleff, 2000). Metals cannot be broken down, and when concentrations inside plant cells rise over threshold or ideal levels, they can cause direct toxicity through cell structural changes (due to oxidative stress induced by reactive oxygen species) and inhibit a number of cytoplasmic enzymes (Assche and Clijsters, 1990). Schmidt (2003) found that increased heavy metal concentrations in the soil can lead to increased crop absorption and a negative impact on plant growth. According to Kuzovkina et al., (2004), cadmium isn't always an essential component of plant metabolism and can be highly phytotoxic, causing rapid death. It has been shown to disrupt enzyme activity, hinder DNA-mediated transformation in microorganisms, interfere with the symbiotic relationship between bacteria and plants, and increase plant susceptibility to fungal invasion (Kabata-Pendias and Pendias, 2001).

3 SOIL WATER POLLUTION AND HEAVY METAL SOURCES

Heavy metal pollution of land and water is a global problem. Every country has been impacted, however the scope and intensity of pollution varies greatly. Heavy metals harmed

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1400000 sites in Western Europe (McGrath et al., 2001), of which over 300000 were poisoned, and the total number in Europe might be substantially higher, as pollution concerns became more prevalent in Central and Eastern European countries (Gade, 2000).

TABLE 1: DIFFERENT SOURCES OF HEAVY METALS

Heavy metals	Sources
As	Semiconductors, petroleum refining, wood preservatives, animal feed additives, coal power plants, herbicides, volcanoes, mining, and smelting are just a few of the industries that make up the semiconductor industry (Nriagu, 1994; Walsh et al., 1979)
Cu	Industry of electroplating, smelting and refining, mining, and biosolids (Liu et al., 2005)
Cd	Metal smelting and refining, fossil fuel burning, phosphate fertiliser application, and sewage sludge are examples of geogenic sources (Baize, 1997) and anthropogenic activities (Nriagu and Pacyna, 1988). (Alloway, 1995; Kabata-Pendias, 2001)
Cr	Sludge, solid waste, tanneries, electroplating industries (Knox et al., 1999)
Pb	Metalliferous ores mining and smelting, leaded gasoline combustion, municipal sewage, Pb-enriched industrial wastes, paints (Gisbert et al., 2003; Seaward and Richardson, 1990)
Hg	Volcanic eruptions, forest fires, emissions from companies manufacturing caustic soda, coal, peat, and wood burning are all examples of natural disasters (Lindqvist, 1991)
Se	Coal mining, oil refining, fossil fuel combustion, glass making, chemical synthesis (e.g., varnish, pigment formulation)
Ni	Volcanic eruptions, land fill, forest fires, bubble bursting and gas exchange in the ocean, and weathering of soils and geological materials are all examples of natural disasters (Knox et al., 1999)
Zn	Industry of electroplating, smelting and refining, mining, and biosolids (Liu et al., 2005)

3.1 PLANTS HEAVY METALS UPTAKE AND RESPONSES

Several prior investigations have revealed plant's ability to bioaccumulate heavy metals from contaminated soil and water. According to studies, using plants in phytoremediation technology to treat heavy metal contaminated areas and to remediate the environment is an alternate method.

Plants respond differently to heavy metal exposure depending on their level of tolerance. Wilting, yellowing, and growth suppression were seen in Chives plants (Allium schoenoprasum) when Ni, Co, and Cd concentrations were 0.25 mM (Goland-Goldhirsh, 2006). Pb and Cr hindered seed germination and reduced plant dry weight on chickpea plants (Cicer auratinum) when metal concentrations and time intervals increased (Dasgupta et al.,2011). Cd stress with 20 µM concentration did not significantly affect root dry weight, shoot height, shoot dry weight, leaf number and total chlorophyll concentration (a and b) of pea plant cv. Kelvedon Wonder except root length compared with the plants grown without Cd treatments (Rahman et al.,2016). The dry weight of maize plant (Zea mays) extremely decreased on Zn-amended soil with increase in Zn doses. At 270 mg kg-1 dose of Zn, shoot and root dry matter production of maize was 468% and 250% lower than control, approximately. The presence of Zn also changed chlorophyll a fluorescence and antioxidant system parameters (Tiecher et al.,2016).

3.2 USE OF BIOTECHNOLOGY TO IMPROVE PHYTOREMEDIATION

The use of biotechnology to generate phytoremediation plants has been investigated. Traditional plant breeding can only combine the qualities needed for efficient phytoremediation using the available genetic variation within a species.

Researchers hypothesized that boosting metal-binding proteins or peptides in plant cells would increase metal-binding capacity and tolerance. Despite the fact that plant cell cultures harboring mammalian metallothionein (MTs) or phytochelatins (PCs) (Rauser. 1995) are more resistant to acute Cd toxicity, the transfer of mammalian MT genes to higher plants appears to have no benefit for phytoremediation. Furthermore, the content of PCs in natural metal-tolerant plants revealed no variation, implying that hyper tolerance to Cd and Zn in these plants was not attributable to PC peptide hyperaccumulation (De Knecht et al.,1992, Harmens et al., 1993). Since mutations that abolished PC production in Arabidopsis and fission yeast resulted in hypersensitivity to Cd (Howden et al., 1995), the evidence supporting the role of PCs is that their existence does correspond with normal levels of metal tolerance. Cd-sensitive (hypo tolerant) single gene mutants of Arabidopsis thaliana, cad1 and cad2, have been discovered and investigated (blocked in glutathione synthesis or PC synthesis). PCs were required for normal tolerance in a plant species with normal tolerance (A. thaliana).

3.3 Advantages

Phytoremediation is less expensive both in-situ and ex-situ than previous processes. The plants are easy to keep track of. The prospect of valuable metals being recovered and reused. It is the least destructive method since it employs naturally occurring organisms and maintains the environment's natural state.

3.4 Limitations

It is impossible to totally avoid the leaching of pollutants into ground water using plant-based remediation techniques. The toxicity of the polluted land and the general conditions of the soil have an impact on the plant's life. Potential bioaccumulation of pollutants, which then made their way up the food chain from primary consumers.

3.5 Future Research Direction

Using molecular biology skills to gain a better understanding of phytoremediation at the genetic and molecular level is one of the study goals in these fields. Investigating the Bio-pathways that are involved in pollutant degradation and sequestration. Determining which genes are involved in the phytoremediation process. Researching cell signaling pathways that influence plant and microbial enzyme expression. The molecular ecology of root-microbial interactions is being investigated. Identifying and analyzing root exudates

4 Conclusions

A phytoremediation can be applied in-situ or ex-situ to a wide range of organic and inorganic chemicals. Phytoremediation is a remediation technique that uses green plants to remove toxins from the environment. Phytoremediation is a green method that can be used to treat heavy metal contaminated environments. Several plants have a great potential as heavy metals bio accumulators and can be employed for heavy metal phytoremediation, according to prior studies.

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