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Ornamental Plant in phytoremediation of contaminated soils: Recent progress and future directions

Keya Mandal[1], Dipti Das[2], Supriya Kumar Bose[3], Arpita Chakraborty[4], Gopal Mistri[5], Joydeep Acharya[6], Aritri Laha[7], Sabyasachi Ghosh[8*]

[1,2,3,4,8*]*Department of Biotechnology, School of life science, Swami Vivekananda University, Barrackpore, West Bengal-700121, India.*
[2]*Department of Environmental Science, Kalna College, Purba Bardhaman, West Bengal-713409, India.*
[3,6]*Department of Botany, Kalna College, Purba Bardhaman, West Bengal-713409, India.*
[5]*Department of Zoology, Kalna College, Purba Bardhaman, West Bengal-713409, India.*
[7]*Department of Microbiology, School of life science, Swami Vivekananda University, Barrackpore, West Bengal-700121, India.*

***Corresponding author:-** Sabyasachi Ghosh*
[*]*Department of Biotechnology, School of life science, Swami Vivekananda University, Barrackpore, West Bengal-700121, India.Email: sabyasachig@svu.ac.in*

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Abstract

Increasing anthropogenic practices for industrialization and rapid gloalization have contributed to problems of metal – induced toxicity, results in severe environmental deterioration. In the current scenario, heavy- metals contamination is a major threat to living beings of the world because of these toxic metals persist in the environment for a prolong time. The phytoremediation is considered as a suitable process in present days to eliminate heavy-metals from environment as its cost-effectiveness, eco-friendliness etc. In the field of phytoremediation, the ornamental plants can be used for dual purpose – cleaning the environment and bringing the aesthetic value to the site. The ornamental plant is used as a test plant because of their high biomass and accumulate more heavy metal concentration from the soil. Moreover, as ornamental plants are not edible, so the risk of biomagnifications and bioaccumulation into the food web is reduced. This comprehensive review highlights recent progress on the applicability and advantages of ornamental plant for the phytoremediation potential in heavy- metals contaminated soil. In addition, briefly discuss on several factors that affecting the phytoremediation techniques of heavy metals and addressed their future directions for sustainable treatment of heavy metals.

Keywords: Heavy- metals, phytoremediation, ornamental plant, biodegradable

1. INTRODUCTION

The age of industrialization and growing technical innovation has altered life style of human beings drustically. An integral part of our agricultural resource is the soil. It has a significant role in Green Revolution and food

security. But a recent time, heavy- metal (HM) toxicity of soil is regarded as a worldwide environmental issue ever to comfort human. Various organic and inorganic substances polluted the environment of the present era. Inorganic substances comprise of macronutrients such as nitrates, phosphates etc and micronutrients such as chromium, copper, iron, manganese etc. Among them, some are hazardous and toxic because of their high concentration beyond the threshold permissible limit. The half – life of toxic heavy- metal is greater than twenty years and remains unchanged for a long period of time in nature (Kapoor and Singh 2021). Acute and chronic continuous exposure of toxic heavy- metal can cause a variety of detrimental impacts on human health. Among them, skin lesions, defects of nervous system, immunological problem, kidney dysfunction, cancer etc are some frequently noticeable health hazards (Briffa et al 2020).

To mitigate toxicity of metals in soil, various physco-chemical and biological processes are adopted. Among them, phytoremediation is an emerging, sustainable and aesthetically pleasant technique that based on the plant interaction (chemical, microbiological, biochemical, physical) in polluted environment to mitigate pollutant's toxic effects. One kind of bioremediation is phytoremediation which can be considered as an advantageous phenomenon where green plants are adopted to eliminate the toxicity of metal –induced pollution. The environmentally supportive technique phytoremediation in which green plants are applied to resque the ecosystem from pollution due to their capability of extraction of heavy-metals and mitigation of soil from toxicity of contaminants (Jitendra Kumar Sharma 2023).

In this context, ornamental plants have been introduced in phytoremediation because of their capacity to mitigate the contamination of soil. Moreover, these ornamental plants provide multiple ecosystem services, contribute to the conservation of biodiversity and beautify the environment by adding aesthetic value. The most important factors for the maximum removal of toxic metal concentration from contaminated soil and well management of phytoremediation design are soil properties, chemistry of metal, types of plants etc (Deepika and Haritash, 2023). Previously, attention was not paid on the dendroremediation of heavy- metal using ornamental plants. This review is expected to be significantly beneficial for improvement of biological heavy - metal treatment process for soil. It is also hoped that this study draw attention to a promising technique merged with the beautification of environment.

2. Sources of heavy metal pollution:

The extreme progress in science and technology poses challenges to protection and conservation of environment. For proliferation of population, development of economic, agricultural and industrial sector leads to the overweighed environmental pollution. Therefore, the driving force for environmental contamination is the prioritization in a particular direction. The sources of heavy metal can be categorized natural and unnatural. The primary natural sources include land erosion, weathering of surface, volcanoes, rock disintegration and other geological processes. On the other hand, principle unnatural sources or anthropogenic sources of metal-induced pollution are growing traffic, farming, mining excavation, industrial sludge etc. The exaggeration development of manufacturing and metropolitan fields is one of the major causes of heavy-metal contamination of soil (Wang et al., 2020). The anthropogenic sources also include automotive industry, paint and varnishes, cosmetics industry etc (Figure 1). The substantial causes of metal-induced pollution of soil are fossil fuel combustion and extensive use of agrochemicals (Peralta et al., 2020).

Figure 1: Multiple sources of heavy-metals

3. Impacts of heavy-metals on environment:

Heavy-metal pollution degrades the soil quality as well as food crops which poses a threat to the mankind at present scenario. Actually, being non –biodegradable heavy-metal toxicants persist in environment for a long period and finally reach to the human body through food chain termed as biomagnifications. Then these contaminants contribute a major effect on genetic material which is expressed as mutagenicity, teratogenicity or carcinogenicity. Cadmium adversely affects the growth and development of food grain like rice (Pramanik et al., 2021). In Indian diet, rice is a staple food. Therefore, high concentration of heavy metal in rice is detrimental to Indian health (Zakaria et al., 2021). Lung cancer is caused by hexavalent chromium. Arsenic poses a deleterious effect on liver, urinary bladder and lung. Other effects of heavy-metal are shown below (table 1).

Table 1: Overview of different toxic metals and their effects.

Toxic metal	Toxic form	Organ system	Mechanism of action	References
Cadmium (Cd)	Cd^{2+}	Bone diseases, Liver damage, Kidney dysfunction	mRNA deregulations, Apoptosis, ROS generation	Fay et al., 2018
Arsenic (As)	As^{3+}	CNS injury, Liver damage	Damage of capillary, Endothelium, Change in eurotransmitter, Homeostasis	Shen et al., 2013
Chromium (Cr)	Cr^{6+}	Kidney dysfunction, Dermal diseases, Lung's cancer	DNA damage, Genomic disorder, ROS generation	Pavesi and Moreira., 2020
Lead (Pb)	Pb^{2+}	Cardiovascular dysfunction, CNS injury, Lungs dysfunction	Reduced GSH, SOD, CAT and GPx levels	Boskabady et al., 2016
Mercury (Hg)	Methyl – Hg	CNS injury, Hepatotoxicity, Renal disorders	ROS generation, Enzyme inhibition	Zhang et al., 2020

4. Phytoremediation of metal-polluted soil:

Heavy-metal contamination of soil which has a deleterious impact on environment becomes an worldwide problems today. Due to the enormously hazards effects of heavy –metal toxicants, the restoration method of soil must be taken with great attention by a novel green technology. In spite of the application of several techniques for reclamation of soil from heavy-metal pollutants which are expensive, not naturally-safe and are responsible for production of secondary pollutants, the emerging technology phytoremediation is considered easy monitoring, environmentally – safe, easy accessible with less constraints for revelation of contaminated soil with a variety of advantages:

- Good public acceptance
- Cost- effectiveness

The application of ornamental plant is the most straightforward approach for phytoremediation due to its high potentials of metal extraction, short life cycle as well as aesthetic value. Besides, these plants reduce the chance of biomagnifications being non-edible. According to Mota et al., (2022), application of ornarnamental potential plants for phytoremediation increases due to their positive economic and social contribution. But it also suffers from some limitations such as slow growth rate, low biomass, time – consuming etc. Application of phytoremediation for mitigation of metal –induced pollution is in laboratory stage at present scenario (Khatiwada et al., 2020). The biological knowledge of plant kingdom at the molecular level is necessary for selection of a particular ornamental plant with high potential of heavy –metal accumulation.

5. Phytoremediation techniques:

Phytoremediation is one of the resourceful bioremediation methods which use accumulator plants to absorb heavy-metal contaminants through rooting system and transferred them to aerial parts of the plant. Several techniques are involved in photoremediation process such as (Figure 2):

Phytoextraction: In phytoextraction process, plant roots extract contaminants from polluted ecosystem and subsequent store the absorbed contaminants in aerial parts of the plants. The accumulator plants, which have TF more than one and BCF more than one, are suitable for phytoextraction (1<TF and 1<BCF) whereTF is the ratio of absorbed heavy metals in plant's shoot to-plant's root and BCF is the ratio of absorbed heavy-metals in plant's root-to –soil (Zakaria et al., 2021).

Phytovolatilization: Accumulated metal pollutants within the aerial biomass are converted into gaseous form with low toxicity and finally released in ecosystem by phytovolatilization techniques.
Phytostabilization: This process converts heavy-metal into less toxic form by decreasing their mobility through secreting redox enzymes in root zone.

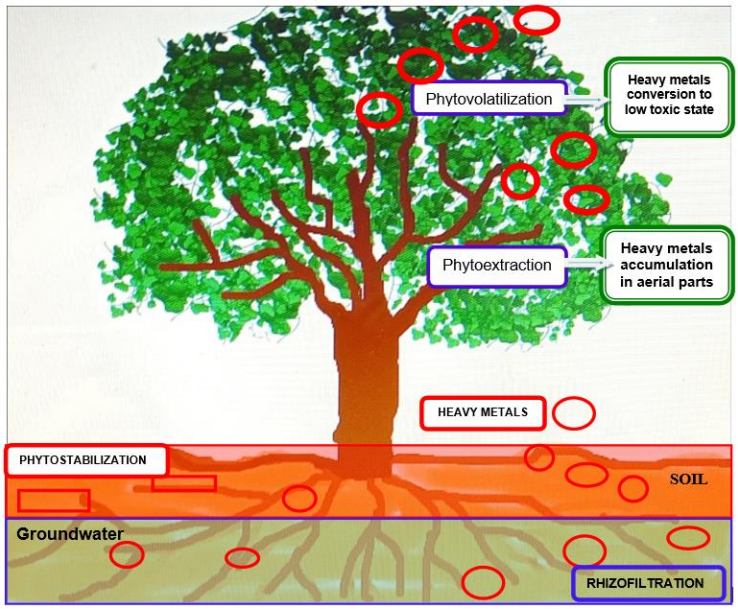

Figure 2. Different techniques involved in phytoremediation process.

6. Factors affecting phytoremediation of heavy metals

The factors affecting phytoremediation are classified into three types- soil properties which include acidity of soil, redox potential, presence of organic substances etc, environmental factors which include climatic condition (temperature, rainfall etc) and plant species include age of plant, amount of biomass, capacity of absorbance etc. These factors control the bioavailability of heavy-metal as well as phytoextraction of contaminants from polluted soil (Sharma et al., 2023).

7. Conclusion

Heavy-metal induced contamination of soil is a burning universal problem to world. As various physico-chemical processes have significant drawbacks, so phytoremediation, being cost-effective, eco–friendly and sustainable green technology, gains public acceptance in developing countries. Utilizing the mitigation potential of ornamental plants, phytoremediation process can successfully restore metal contaminated soil in a novel way because of its wonderful nature such as simplicity, environmental compatibility etc. The conclusions drown on the basis of review literature is that the ornamental plants can minimize the toxicity of a variety of heavy –metal without changing ecosystem. Moreover, ornamental plants add aesthetic value as well as beautification to the surrounding environment. Besides, as these plants are not edible, so the entrance into food chain of toxicants termed as bioaccumulation and biomagnifications becomes decreased. Future studies need more information from fieldwork and risk assessment monitoring, so that phytoremediation using ornamental plants would be commercially used on large scale.

8. Future Directions

Nowadays, among various conventional technologies, phytoremediation process for reclamation of heavy-metal polluted soil has been proven to be a promising green technology. But it has some limitations. Besides, no single techniques can adequately restore the metal-induced soil. To overcome this problem, with the help of genetic engineering, chelate assisted and microbe assisted phytoremediation strategies using ornamental plants would be significantly suitable in future. Genetic Engineering is a powerful tool to induce desired traits like huge biomass, fast grow, high tolerance capacity to toxicants, high adaptation power to any weather condition etc into the ornamental plants. Currently, phytoremediation is in its nonage and many technical obstacles need to be scrutinized. The physiology and molecular biology of hyper-accumulator ornamental

plants need to be explored more about. Accurate cooperation of the dynamics plant –heavy metal interaction, maximization of process, proper removal of produced biomass is still needed. In future, phytoremrdiation will play an important role to achieve the Sustainable Development Goals.

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