A Review on Phytoremediation and Microbial Remediation of Heavy Metals Management

[1*]Thakur Pitambri, [2]Rahul Hakhu, [1]Mehak, [1]Mannat Malhotra, [1]Anurag Khatri

[1]Department of Biotechnology, University Institute of Biotechnology (UIBT), Chandigarh University, Mohali, Punjab 140413, India
[2]Centre for Distance and Online Education, Chitkara University, India

*Corresponding author: pitambri.cu@gmail.com

ABSTRACT:

This review is mainly focused on the removal of heavy metal from the environment by using various plants and microorganisms. Substantial Metal (HM) tainting issues are getting progressively basic in India; aimless utilization of these for human benefits like horticulture, modern, foundries, mining, smelters, coal-consuming force plants and metallurgical has changed their air biochemical parity. These outcomes in overabundance arrival of metals, for example, cadmium, chromium copper, nickel, iron, zinc, and so forth are bigger ecological contaminations, especially in zones with higher anthropogenic movement. The presentation of people to substantial metals can happen through different ways, which incorporate inward breath as residue or smoke, vaporization, and ingestion through various contaminated food material or may be some soft drinks. This review provides a comprehensive overview of the mechanisms used by plants and microbes in heavy metal uptake, transformation, and stabilization. It discusses key processes such as phytoextraction, phytostabilization, bioaccumulation, biosorption and biomineralization with high remediation potential. Recent advancements, limitations and future prospects for field-scale application are examined to understand the potential of integrated bioremediation approaches in restoring contaminated environments.

KEYWORDS: Bioremediation, Toxins, Heavy metals, Environment, microorganisms, phytoextraction

1. INTRODUCTION

Contamination of the earth continues expanding at a disturbing rate because of the exercises of man, for example, urbanization, innovative headway, dangerous horticultural and industrialization which corrupts the earth. Substantial toxins which are discharged to the nature are constant because of their danger which represents an extreme risk to living beings presented to significant levels of these contaminations. Metals are used as a fundamental for natural elements such as plants yet at raised levels; these are metabolic responses in frameworks of living beings. Poisonous substantial metals, for example, lead, cadmium, gold, mercury, chromium, uranium, selenium, silver, nickel and arsenic and Zn these are not valuable for different plants, and equipped for decreasing the plant development because of diminished photosynthetic exercises, plant mineral sustenance, and diminished movement of fundamental chemicals [1]. Metals are mainly cytotoxic at low focuses and may increase malignant growth in people [2]. These dangerous metals could mass in the body when expended in debased nourishment through the natural way of life [3]. These causes oxidative pressure, and unevenness thus, decrease the destruction of cells or help in fixing the harm [4]. Substantial metal poisonous quality builds the ROS (Reactive Oxygen Species) generation consequently diminishing the cancer prevention agent frameworks (glutathione, superoxide dismutase, and so forth.) which ensure cells. On the off chance that this condition precedes, the ordinary working of the living being is influenced and may constantly prompt cell demise.

Bioremediation is step by step being acknowledged as practices for reclamation to overwhelming soil contaminated with toxins. As its highly eco-accommodating and financially savvy contrasted with the ordinary concoction and physical techniques, which are frequently extravagant and incapable when metal fixations are low, not withstanding creating critical measures of harmful ooze [5]. The capacity of microorganisms to debase toxins relies upon the appropriateness of natural condition for development and digestion that incorporate reasonable pH, temperature and dampness [6]. This

survey examines the impacts of substantial metals upon the surface of earth and methods for their remediated utilizing plants and various microorganisms. Mainly, potential possibilities and impediment of hereditarily adjusted living beings for bioremediation are likewise examined.

Within, development of industry, there is a significant increment on the release of modern waste material into the nature, essentially in soil or water, which mainly prompted aggregation of overwhelming toxins, particularly in the urban areas. Slowly exhaustion for overwhelming metals additionally happens through draining, plants take-up, disintegration or collapse. Thus, aimless arrival for overwhelming metals to dirt and water is a significant wellbeing thing to be concerned about in all around the world, they can't get separated into less-harmful structures or subsequently depend upon the biological system. Huge numbers of these are poisonous like; arsenic, silver, cadmium, lead, copper, chromium, mercury, selenium, zinc and nickel those are harmful as well as cancer-causing and mutagenic in nature [1]. Plants require a very low number of metals for the development or their ideal execution. In any case, the expanding grouping of a few metals in soil and waters because of mechanical upset has made a disturbing circumstance in life of human being and sea-going biota. It is apparent from different reports referring to hurtful impacts of overwhelming metals on human wellbeing. So as to make the earth more advantageous for people, sullied water bodies or land should be redressed to eliminate the substantial metals from them and follow components. A few strategies to expel these substantial metals consist of compound precipitation, then oxidation or decrease, filtration, particle trade, switch assimilation, layer innovation, dissipation and electrochemical treatment. However, a large portion of these systems become insufficient thus, groupings of harmful metals are under 100 mg/L [7].

Most harmful salts of metals are soluble in water and easily broken in wastewater thus, they can’t be isolated from physical partition strategies [2]. Also, physico substance strategies are inadequate or costly when the convergence of substantial metals is low. On the other hand, organic techniques like biosorption or potentially bioaccumulation for evacuation of toxins may act as an alluring option to physico-substance strategies [3]. Utilization of various microbes or certain plants for their removal of toxins designs is accordingly a potential answer for overwhelming toxin contamination. According to Aristotle et al, (2021) [8] bibliometric analysis indicates good results for the heavy metal removal by microalgal biosorption method. For heavy metal biosorption microalgae serve a promising feedstock due to its fast growth.

So, it incorporates supportable remediation advancements for amend or restore the normal state of soil. Be that as it may, presentation of overwhelming toxin to dirt leads to impressive alteration of microbial network, in spite of their imperative significance for the development of microorganisms at moderately low focuses [4]. The adjustment of the microbial make up is for the most part realized by applying an inhibitory activity through blockage of fundamental useful gatherings, relocation of basic metal particles or change of dynamic adaptations of organic atoms [9]. Thus, reaction of various microbial networks to overwhelming metals depends upon Sustainability, fixation and accessibility of substantial metals and is an intricate procedure which is constrained by various components, for example, sort of metals, mediums nature, and various microbial species [5].

2. BIOREMEDIATION

To expel ecological contaminants from the biological system bioremediation procedure is used. The organic systems innate in microorganisms and plants are used to kill unsafe toxins and reestablish the biological system to unique situation [10]. The fundamental standards of bioremediation include decreasing the dissolvability of these ecological contaminants by evolving pH, the redox responses and adsorption of contaminants from dirtied condition [11]. For instance, the biosorption capacities of *Aspergillus niger* [12] and *Mycobacterium chlorophenolicum* [13] in the expulsion of PCP (phencyclidine) from watery arrangements were accounted for pH-subordinate. Brandt et al. (1997) [13] likewise assessed the impact of pH on adsorption by *Mycobacterium chlorophenolicum* and revealed that pH esteems were a fundamental parameter with adsorptive limit expanding diminished pH. According to Jianlong et al (2000) [14] at pH 6–8, best outcomes on adsorption conduct of phencyclidine were obtained. The outcomes acquired through different creators feature significance utilizing fitting pH for ideal execution of microorganisms utilized. Bioremediation innovations depend on changing the science and microbiology of water [15]. Redox responses include artificially changing hurtful contaminants

into harmless or less poisonous intensifies that are progressively steady, less portable [16]. It assumes a fundamental job in the change of harmful substantial metals, into harmless structures [17]. Redox responses in tainted soil silt and groundwater are regularly influenced by the medium, yet this can be controlled by expansion of natural changes, for example, fertilizers and biochar [18]. The utilization of natural alterations, by evolving pH, diminishing the solvency of substantial metals and expanding accessible supplements [19].

Biochar is a result of pyrolysis of biomass for example, crop buildup, and excrement and strong squanders [20]. Far reaching audits by a few creators have depicted estimation of biochar as a successful operator in immobilization of metals and natural poisons [21]. Biochar can give, acknowledge or move electrons inside their surroundings abiotically or through organic pathways [22]. According to certain scientists that biochar may likewise encourage microbial electron carrying forms show comparative utilitarian attributes to soil redox-dynamic natural issue [23]. Biochar acts by expanding the pH of debased soils accordingly influencing the bioavailability of overwhelming metals for plant take-up. Tandon et al (2013) [24] detailed another oxidative course for change of As (III) to As (V) utilizing earth bolstered zerovalent iron nanoparticles by blending ferric nitrate in with alcohol of financially accessible tea. Bioremediation adequacy relies upon a few factors, for example, the nature of the life forms used, the predominant ecological components at the defiled site, just as the level of the contaminations in that condition [25]. Bioremediation can be accomplished with the utilization of microorganisms (microbial bioremediation) which relies upon the metabolic capability of the microorganisms to corrupt ecological toxins and change them to harmless structures through redox forms [26]. It can likewise be done by plants which tie, remove and remediate toxins from nature (phytoremediation).

3. DIFFERENT EFFECTS OF HEAVY METAL

3.1 Effect on environment

Metals mainly are the components which are generally present in soil. However, if these metals are present in high amount, then, these may become toxic for the animals, plants as well as for the microbes. The most important and commonly used heavy metal which plays an important role in contaminating the environment are arsenic, stronium, caesium, cadmium, chromium, mercury, lead and zinc mainly. Whereas, there are some metals which are required by the plants for their growth and development such as Zn, Cu, Ni, Mn and Co which are mainly used as micronutrients. Whereas, on the other hand heavy metals including lead, cadmium and magnesium having unknown biological functions. Mainly, the heavy metals present naturally in the atmosphere as well as created through humans in the environment. Naturally occurring sources involves soil erosion, rock weathering and volcanic activity during mining, smelting and electroplating. Mainly, the use of fertilizers pesticides and solids which are found in agriculture, dumping of sludge in soil, atmospheric deposition on ground and industrial discharge into river etc. these all comes under man-made sources [24].

3.2 Effect on soils microbial activity

There are some toxins present in the soil which are req. for the proper development of soil microbe. The participation of soil microbe is required for biochemical reaction of the soil. These microbes play vital role in maintaining the quality of soil and formation of soils organic matter and decomposition of harmful substances [26]. Heavy metal contaminated soil has a harmful effect on the microbial properties of soil, such as enzymatic activity of the soil which depend on the organic matter and other chemical properties and pH. High concentration of heavy metal affects microbial activity which is present in the soil and seriously threatened the functioning of soil ecosystem. Due to increase in the concentration of toxins the concentration of enzymatic activity is reduced due to interaction of microbes enzyme and toxins, which is not associated to microbes reduction. Contamination due to toxins changes the soils chemical or biological properties. It is an indication for knowing the adverse effect of toxins on various microbial communities of the soil [27].

3.3 Effect on aquatic life

Different pollutants are released from various natural and anthropogenic sources which are exposed to freshwater bodies. Heavy metal affects the aquatic life i.e. fish which has become a global issue because it causes health risk to the consumer [28]. Fish has a high level of unsaturated fatty acid and low cholesterol level which is a vital source of protein. For a

balanced diet use of edible fish is necessary. But the contamination of aquatic freshwater (fish) by toxic heavy metal increases the risk of human health including women, children, and people suffering from other diseases. The heavy metal bioaccumulation in aquatic fishes which depends upon different factors. The toxins accumulation in different tissue of fish depends upon the structure and function of tissue which include gills, liver and kidney have maximum addition of heavy metal in comparison with other tissues. These affect the health of aquatic life, wellbeing and when these heavy metals enter the human internal system through food chain and thus, have a harmful effect on health of humans. It was said that contamination through toxins in fresh water causes stress in Channa punctatus make it weak and become easily affected by diseases [29]. Heavy metal causes population decline of aquatic species.

3.4 Effect on human health

There are several routes by which humans get exposed to toxins including ingestion, and dermal absorption and inhalation. In developing countries there is more exposure of people toward heavy metal [30]. Generally, the people of developing countries don't have knowledge or awareness about heavy metals and their harmful effects on human health. There are various mining and industrial operations in which the workers working there inhale the metals directly in the form of dust particles. Humans using amalgamations process for the extraction of gold which gets exposed to harmful Hg vapors. It's reported that the welders are highly exposed to welding fumes which consist of high level of toxins like Cr, Ni, Cd, and Pb in blood which shows increased oxidative stress [31]. The entry of Cd into the body is through cigarette smoking. The toxins such as Cd, Pb, Hg and As lead to the reduction of the major antioxidants of cells. These metals increase the generation of reactive oxygen species (ROS). The increase in the (ROS) decreases the defense of cells which lead to" oxidative stress". The patients suffering from cancer and diabetes have lower concentration of antioxidant element such as Se and higher conc. of harmful toxins i.e. Cr and Pb, Cd.

Table 1: Some of the toxins which affect human health.

Serial Number	Heavy Metals.	EPA Regulatory Limited (ppm).	Toxic Effects.	References
1.	Ag	0.10	Turning of skin and other body tissues to gray or blue-gray, breathing problems, lung and throat irritation and stomach pain.	[32]
2.	As	0.01	Affects the processes such as oxidative phosphorylation and ATP synthesis.	[32]
3.	Ba	2.0	Cause cardiac arrhythmias, respiratory failure	[29]
4.	Cd	5.0	Carcinogenic, mutagenic, endocrine disruptor, lung damage and fragile bones, affects calcium regulation in biological systems.	[30]
5.	Cr	0.1	Hair loss.	[29]
6.	Cu	1.3	Brain and kidney damage	[32]

7.	Hg	2.0	Autoimmune diseases, depression, drowsiness, fatigue, hair loss, insomnia, loss of memory.	[30]
8.	Ni	0.2	Allergic skin diseases such as itching, cancer of the lungs, nose, sinuses, throat through continuous inhalation, immunotoxic, hair loss.	[28]
9.	Pb	15	Excess exposure in children causes impaired development, reduced intelligence, short-term memory loss, disabilities in learning and coordination problems, risk of cardiovascular disease.	[1]

3.5 Effect on air

According to (EPA, 2000) [33], air pollution is defined as a key environmental and social issue which causes multiple challenges in terms of management and migration of harmful Pollutants. The most important environment related health concern is the emission of air pollutant from anthropogenic and natural sources (European environment agency 2000). Heavy metals which are involved in air pollution are As, Pb, and Ni and Cd concentration of each metal in EU cities: Arsenic: 94% of stations announced an incentive beneath 2.4ng/m3 (lower than the appraisal edge characterized in EU enactment) (EU, 2004) concentration above target value (6ng/m3) in urban regions in Belgium, Poland, Finland. Cadmium: 98% of station identified centralizations of Cd beneath 2ng/m3 (lower than the appraisal limit characterized in EU enactment) (EU, 2004). Concentration above target esteem 5ng/m3 estimated at 6 stations in rural mechanical territories in Belgium, Italy and Spain. Lead: 99%of the stations identified groupings of Cd beneath 2ng/m3 (lower than the appraisal edge characterized in EU enactment) (EU, 2004) levels above 0.5µg/m3 were distinguished uniquely at a Belgian station. Nickel: 97% of stations revealed groupings of Ni beneath 10ng/m3 lower than the appraisal edge characterized in EU legislation) (EU, 2004). Concentrations of more than 20ng/m3 were distinguished at a mechanical station in Norway and at another station in the unified realm.

4. VARIOUS PLANTS USED IN BIOREMEDIATION

Latterly, sunflower species (Helianthus annuus) were most utilized for the removal of natural toxins and overwhelming metals because of these plants capacity to take up substantial metals from the earth. The site from where these are collected from substantial metals varies starting with one plant then onto the next. A few creators have detailed collection of overwhelming metals primarily in the underlying foundations of sunflower with development from roots over the ground mass [34] Madejon *et al* (2003) while others revealed compelling development from roots to over the ground mass. Angelova et al (2016) [35] indicated that dissemination of overwhelming metals in organs of sunflower is specific for each metal since 59% Pb aggregated in the leaves of these plants with a low concentration of 1% amassed in seeds. Comparable perceptions made for Cd and Zn which aggregated 79% and 47% in sunflowers leaf, individually. Hyper accumulator plants, for example, certain species of Brassicaceae like (Brassica rapa, Brassica napus and Brassica juncea) are quick producers having high biomass. The outcomes acquired by Islam et al (2013) [36] uncovered the productivity of Micranthemum umbrosum as a proficient collector of Cd and a hyper-gatherer of as poisonous quality. In spite of the advantages of phytoextraction, its adequacy may be hampered if the overwhelming concentration of metal is high, barely any biomass is delivered by plants or development rate is moderate, which impede metal take-up. Thus, in phytoextraction procedure it may be upgraded by utilizing chelators, for example, citrus extract and EDTA which increment portability of

soil overwhelming metals or the utilization of natural enhancements, for example, chicken excrement which demonstrated to build development of Rorippa globosa species and diminished soil-extractable Cd and centralizations of Cd [37]. The presence of soil on dirtied site and the level of metal defilement decides the rate at which hyper accumulating plants remove toxin from that site. Consequently, inquire about must be intended to distinguish hyper accumulating plants that are quickly developing with the capacity to gather bottomless biomass tolerant to a few metals.

Research towards ID of hyper accumulating plants should concentrate on assessment of the impact of metals weight on advantageous microbes inside the rhizosphere and harvests, and growing better uses of bioremediation innovations for removal of toxins from tainted soils [3]. These recommendations made by Tak et al (2013) [3] are key as they will enable analysts to utilize the fitting hyper accumulating plants to get the best outcomes in phytoremediation of contaminated situations. The effectiveness of phytoextraction depends on a few variables such as plant utilized, level of plant resilience to metals and plant limit to take-up metals [38]. Phytoextraction can be financially practical; other than expulsion of overwhelming metals from the dirt, it likewise delivers biomass with included worth. Phytoextraction is most favored strategy utilized by plants is upgraded by plant development advancing Rhizobacteria (PGPR) related with the plant roots.

Table 2: List of plants utilized for the heavy metals removal

Serial Number	Heavy Metals	Plant Species	References
1.	Cd, Cu, Pb, Zn	Salix spp. (*Salix viminalis, Salix fragilis*)	[38]
2.	Cd	Castor (*Ricinus communis*)	[22]
3.	Cd, Pb, Zn	Corn (*Zea mays*)	
4.	Cd, Cu, Pb, Zn	Populus spp. (*Populus deltoides*, *Populus nigra*, *Populus trichocarpa*)	[38]
5.	Cd, Cu, Ni, Pb	Jatropha (*Jatropha curcas* L.)	[39]
6.	Hg	Populus deltoides	[40], [41]
7.	Se	Astragalus bisulcatus Brassicajuncea,	[42]
8.	Zn	*Populus canescens*	[43]

5. CONCLUSION

Phytoremediation and microbial remediation are environment friendly sustainable approach for the management of heavy metals contamination in soil, and water bodies. This review was mainly focused on the adverse effect of heavy metals on air, water, soil, environment and human health and their remediation by the use of ecofriendly methods such as by using plants and microorganisms. The amount of these toxins is now a days increasing due to industrialization which releases harmful toxins in the environment as well as in the natural water which lead to various human health diseases mainly breathing related problems. So, to overcome this problem various plants were used which are helpful in removing the toxins up to certain extent. Continued research into genetically enhanced organisms, microbial consortia and field-optimized techniques is important to overcome current limitations and translate laboratory findings into effective real-world solutions. Integrated bioremediation holds significant potential for restoring polluted ecosystem in cost-effective and sustainable manner.

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