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Bioremediation by Plant Growth Promoting Rhizobacteria

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ABSTRACT

The contamination of soil and water with heavy metal pollutants is escalating day by day due to excessive industrialization, waste disposal, agricultural applications and various anthropogenic actions. Accrual of heavy metals, as non-biodegradable agents, pose serious environmental concerns for all life forms affecting mostly plants and therefore present a risk to health of humans due to food chain contamination. To avoid heavy metal problems, bioremediation via PLANT GROWTH PROMOTING RHIZOBACTERIA (PGPR) is getting more consideration due to ecofriendly nature, less expense and proven efficiency in comparison to physical or chemical remediation methods. Improving growth of plants and conquering the metal toxicity can be enhanced by association of PGPR. These microbes colonize the root or inhabit near root surfaces and involve in mechanisms for plant prevention from toxicity through secretion and production of several regulatory compounds such as phytohormones, siderophores, metal binding proteins etc. The review accentuates the role of PGPR in accelerating phytoremediation for elimination of toxic metals and growth augmentation of plants.

KEY WORDS: Bioremediation, Heavy metals, Exploitation of PGPR, Bacterial interaction

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1. INTRODUCTION

The constant increase in industrialization, agricultural practices and several anthropogenic activities worldwide has caused extensive environmental problems due to the release of toxic pollutants, such as heavy metals, organic pollutants,etc.[1] Now a day's world is facing environmental problems, such as soil contamination with pesticides, metals or hydrocarbons contamination, disposal of animal manure, treatment of waste water or recovery of reusable products and energy from waste materials. Among all the hazardous pollutants toxic metal ions are very important to control because they accumulate through biological food chain[2]. As a result, bioremediation is becoming increasingly used mostly in case of removal of trace metal from polluted environment, as a cheaper alternative to chemical technologies. Soil contamination by organic compounds like industrial waste, petroleum products, solvents and heavy metals (i.e. Cr, Cd, Zn, Cu, Hg) are important environmental problems worldwide and have negative impacts on both human health and agricultural productivity[3]. Heavy metals are the main inorganic pollutants which are water soluble and accumulate in the biosphere of soil because of their non-degradable property and consequently disturb the environment (mostly plants) and make the food chain contaminated. Apart from such fact when the amount of heavy metals increased around the microbial environment which cause the deleterious effect on cell multiplication, growth and development of microbial world[4].

Metal can also be classifying as 1) essential metals with biological functions 2) toxic metal 3) nonessential, nontoxic metal with no biological functions[5]. The noxious trace elements are in different valence states including zinc (Zn), mercury (Hg), arsenic (As), chromium (Cr), cadmium (Cd), nickel (Ni) and lead (Pb) copper (Cu). Some of the trace elements are required by plants as micronutrients in minute quantities but disproportionate accrual of heavy metals is detrimental to the majority of plants. When heavy metal ions are present in elevated levels in the environment, plant roots rapidly absorb and translocate them to shoots and leaves which cause stress leading to disturbed metabolism, reduced growth and even plant death[6].

There is absolutely no time to lose to feed this growing population, the world needs to start to greatly increase agricultural activity and productivity to do so in a sustainable andenvironmentally friendly manner. To feed the growing population, it is necessary to reexamine many of the existing approaches to agricultural science that includes the use of chemical fertilizers, herbicides, fungicides, pesticides and insecticides[7].Agriculture and human health will likely make much greater use of both transgenic plants and plant growth promoting rhizobacteria, or PGPR.One way to address this problem is through the use of phytoremediation, use of plants to take up and concentrate or degrade a broad range of environmental contaminants[8]. Moreover, addition of PGPB to plants that are used in phytoremediation protocols typically makes the entire remediation process much more efficient[8].Bioremediation of heavy metals can be achieved by use of PGPR to perform absorption, oxidation, reduction, precipitation and degradation of heavy metals[9].

2. BIOREMEDIATION BY PLANT GROWTH PROMOTING RHIZOBACTERIA (PGPR)

Bioremediation term referred as use of biologically mediated agent/process to detoxify, degrade or transform pollutants to an innocuous state[10]. Potential biological tools for bioremediation are Biosorption and bioaccumulation of heavy metals by PGPB[11].Biosorption is interaction with heavy metal by non-enzymatic means; adsorption whereas Bioaccumulation is energy dependent heavy metal transport system[12].The most widely studied group of PGPB is plant growth promoting rhizobacteria (PGPR)[13]. Soil is replete with microbial life forms including bacterial population, fungi, actinomycetes, protozoa, and algae. Bacteria are by far most common among them approximately 95%[7]. The most broadly studied group of plant growth promoting bacteria are plant growth-promoting rhizobacteria (PGPR) which is colonizing the root surfaces and the closely adhering soil interface; the rhizosphere. Among the wide population of PGPR some of them can also enter root interior and establishits endophytic populations.

Figure 2.1 shows the movement of heavy metals from plant roots to different vascular system of plant. Many of them are also able to transcend the endodermis barrier, crossing from the root cortex to the vascular system, and subsequently thrive as endophytes in stem, tubers, leaves, and other organs of plants[13]. This complex relationship of plants and rhizospheric bacteria often tends to improvement of the plant growth. Currently studied things are understanding of bacteria and positive impact on plant growth and health. Many organisms are living freely surround the plant roots. I.e. rhizospheric bacteria; participating in variety of functions.

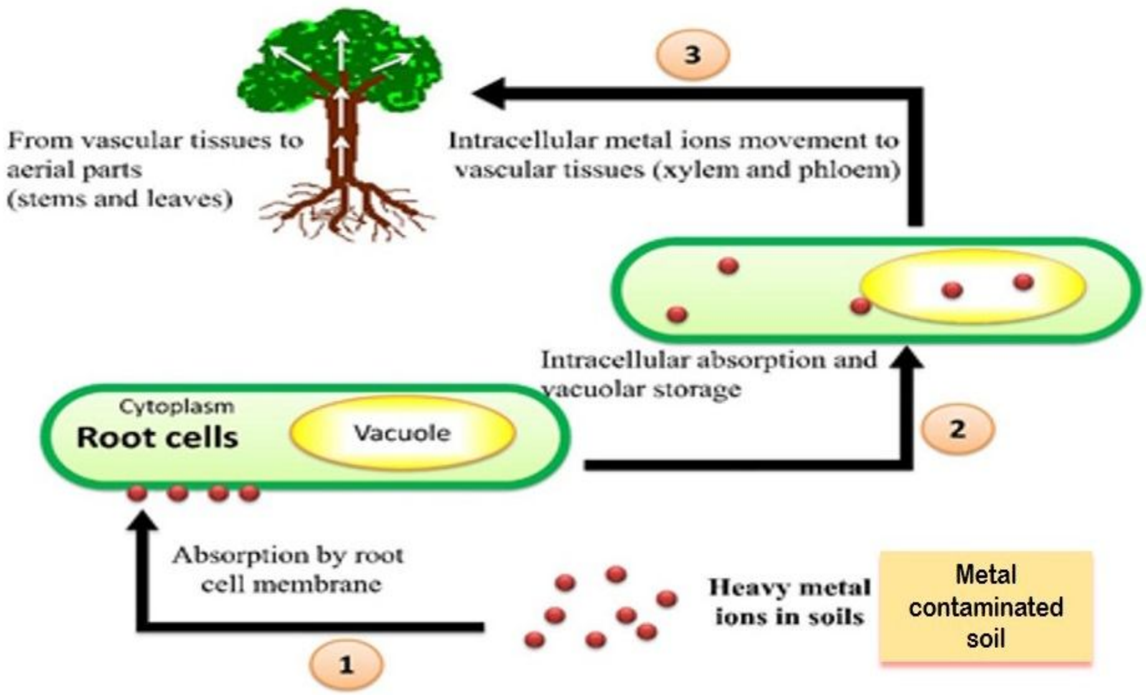

Figure 2.1:Graphical presentation of the movement of heavy metals in plants (adopted and manipulate[16]

Conceptually, PGPB affects plant growth either directly or indirectly. Direct promotion of plant growth occurs when either (i) the PGPB facilitates the acquisition of resources from the environment including nitrogen, phosphorus and iron or (ii) modulate plant growth by PGPB providing or regulating various plant hormones. Indirect promotion of plant growth by PGPB occurs when a bacterium limits or prevents the damage to plants that might be caused by various pathogenic fungi and nematodes. There are a large number of common mechanisms that PGPB used to indirectly promote plant growth including production of antibiotics, cellwall degrading enzymes, lowering plant ethylene levels, induce systemic resistance, decreasing amount of iron available to pathogens and the synthesis of pathogen inhibition of volatile compounds[14].

3. EXPLOITATION OF PGPR

Industrialization increases exploitation and commercialization. Heavy metals are directly in contact with industries as a major available site. Few metal ions and its sources are mention in table-3.1.

Table 3.1: Some of the common industrial units releasing toxic heavy metals into environment are listed below[15].

Sr. no.	Heavy metals	Sources
1	Copper	Electroplating industry, plastic industry and industrial emissions, metal refining industries
2	Chromium	Tanning industries, Chrome plating industries, Electroplating industries, leather mining industries, textile manufacturing industries.
3	Iron	Galvanization of engine parts, machines manufacturing, metal refining industries
4	Mercury	Thermometer manufacturing industries, adhesive, paint, light bulb industry, leather tanning industry, caustic soda emissions
5	Lead	Pesticides, paints, automobile parts, batteries manufacturing, petrol based material
6	Cadmium	Phosphate fertilizers, pesticides production, metal smelting and refining, PVC production and refineries, copper refineries, paint
7	Zinc	Paints, dyes, rubber industries, wood preservatives and ointments.

For more comprehensive commercialization of plant growth promoting bacterial strains, a number of issues need to be noticed. it includes (I)determination of those traits that are most important for satisfactory functioning and successive selection of PGPB strains with basic biological activities; (ii) compactness among regulatory agencies in different countries regarding what strains can be released to the environment, and under what conditions genetically engineered strains are suitable for environmental use; (iii) a better understanding of the advantages and disadvantages of using rhizospheric versus endophytic bacteria; (iv)selection of PGPB strains that function optimally under specific environmental conditions (e.g., those that work well in warm and sandy soils versus organisms better adapted to cool and wet environments); (v) development of more effective means of applying PGPB to plants in various settings (e.g., in the field versus in the greenhouse); (vi) a better understanding of the potential interactions between PGPB and my corrhizae and other soil fungi. PGPB mediated plant growth promotion occurs by the alteration of the whole microbial community in rhizosphere niche through the production of various substances (Table-1).

Table 3.2: Growth promoting substances released by selected plant growth promoting bacteria (PGPB) (adopted[16])

Plant growth promoting rhizobacteria	Plant growth promoting traits
Pseudomonas putida	IAA, siderophores, HCN, ammonia, EPS Phosphate solubilization
Pseudomonas aeruginosa	IAA, siderophores, HCN, ammonia, EPS Phosphate solubilization
Rhizobium sp. (pea)	IAA, siderophores, HCN, ammonia, EPS
Mesorhizobium sp.	IAA, siderophores, HCN, ammonia, EPS
Bradyrhizobium sp.	IAA, siderophores, HCN, ammonia, EPS
Klebsiella sp.	IAA, siderophores, HCN, ammonia, EPS Phosphate solubilization
Pseudomonas sp. A3R3	IAA, siderophores
Rhizobium sp. (lentil)	IAA, siderophores, HCN, ammonia, EPS
Psychrobacter sp. SRS8	Heavy metal mobilization
Enterobacter asburiae	IAA, siderophores, HCN, ammonia, EPSPhosphate solubilization
ACC: 1-aminocyclopropane-1-carboxylate; EPS: exopolysaccharides; IAA: indole acetic acid	

4. MECHANISM OF ACTION

Microorganisms follow many metal ion uptake mechanisms[17]. Best-studied mechanisms of bacterial plant growth promotion include providing plants with resources/nutrients that they lack such as fixed nitrogen, iron, and phosphorus. If any agricultural soils lack a sufficient amount of one or more of these compounds so that plant growth is suboptimal. To obviate this problem and obtain higher plant yields, farmers have become increasingly dependent on chemical sources of nitrogen and phosphorus. Besides being costly, the production of chemical fertilizers depletes on renewable resources, the oil and natural gas used to produce these fertilizers, and poses human and environmental hazards. It would obviously be advantageous if efficient biological means of providing nitrogen and phosphorus to plants could be used to substitute for at least a portion of the chemical nitrogen and phosphorus that is currently used.

Phytoremediation is another tool for remediation of metal ions which includes biological source – plant in absorption of metal ions[8]. Phytoremediation exploits plants's innate system for human benefits. It involves four major steps: (I) Phytoextraction (II)Phytovolatilization (III) Phytostabilization (IV) Rhizofilteration[8].PGPR adhere to the plant roots by means of colonizing and the developing root system.

5. PGPR INTERACTION WITH PLANT FOR HEAVY METAL REMOVAL

PGPR have enabled themselves to bioavailability of trace elements via release of chelating substances followed by acidifying microenvironment of contaminated site. The specialty of heavy metal tolerant PGPR interaction with plants is totally dependent reaction on soil, environment, type of plant, metal contamination bioavailability, level of nutrition. These factors can make interaction specific and nonspecific depends on situation available. Bacterial interaction may limits by various factors like halting plant growth in heavy metal stress condition, low water supply, soil structure lacking. The pH effect is one of the main factor influencing metal availability[18]. Sensitivity of microorganisms towards heavy metals make them prospective mediators for bioremediation. PGPR can change plant cellular functions on basis of environmental conditions; plant is able to cope with different trace elements level and can achieve resistance on heavy metals. Soil and water metal contamination in increasing direction leads best cope for plant towards heavy metals resistance. Potential PGPR is also having phytoremediation according to new study[6]. Fig-5.1 is showing different ways of interaction of bacterial cell as PGPR and heavy metal ions which acts as pollutant.

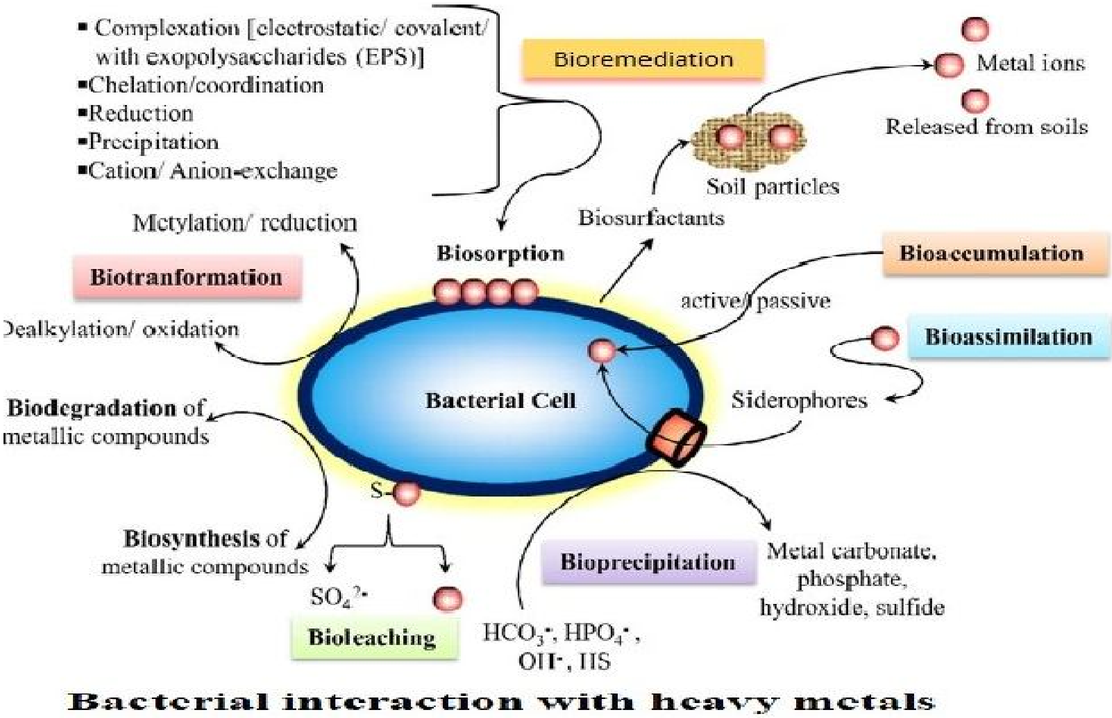

Figure 5.1: Depiction of various types of bacterial interaction with heavy metals in metal polluted soil (adopted and manipulate[16]).

6. CONCLUSION AND PERSPECTIVES

Research over the past decades has provided a better understanding of heavy metal pollution in every environmental parameters and understanding of usefulness. Bio conservation of nature is one of the effective aspect by using biological resources themselves for better life of human beings. Society of researchers develops cost effective technologies that can find a very broad-spectrum applications of removal of trace element concentration from soil and water. Biological degradation of heavy metals by microorganisms especially plant growth promoting rhizobacteria interact with soil contamination particles by means of bioremediation. Equally, Microbial biomass (PGPR) with high potential for metal uptake needs further more investigation with goal of exploring potency of metabolic activity and their waste management system. Heavy metal remediation/degradation can be achieved by immobilization technique, concentration and partitioning to an environmental compartment, thereby minimizing the anticipated hazards[19]. Rhizospheric PGPR can promote plant root establishment and durability by adhering to root surfaces and using root exudates for growth by synthesizing amino acids and vitamins.

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