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BIOREMEDIATION ON HEAVY METAL IN AGRICULTURAL FIELD BY MICROBES

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ABSTRACT

Soils and rivers have become heavily polluted with heavy metals due to rapid industrialization and anthropogenic practices such as the unmanaged use of agro-chemicals, fossil fuel burning and disposal of sewage sludge. Heavy metals are non-biodegradable and remain in the atmosphere. To avoid heavy metal leaching or mobilization into environmental segments and to encourage their extraction, remediation is therefore necessary.

Several scientific studies on the bioremediation of heavy metals using microorganisms have been performed. There is, however, a lack of knowledge on the use of synergistic heavy metal resistant bacteria and fungi for heavy metal bio-remediation.

In areas with low metal toxicity, traditional and physical methods are costly and not reliable. Heavy metal exposure does significant harm to the natural ecosystem leading to numerous health risks to humans and plants. While most bacteria are usually toxic to heavy metals, there are some bacteria that are heavy metal tolerant and can grow in their presence, once established, heavy metal tolerant bacteria are used for Bioremediation. Bioremediation is thus

an eco-friendly and effective way of reclaiming habitats polluted with heavy metals by making use of the intrinsic biological processes of microorganisms and plants to remove dangerous pollutants.

The present work briefly describes the presence of heavy metals in the atmosphere and, as stated in the review literature, methods for using microorganisms for bioremediation processes.

Keyword: Bioremediation, Heavy metals, Environmental hazard, Pollutants, Eco-friendly

INTRODUCTION

Heavy metals like lead (Pb), chromium (Cr), cadmium (Cd), mercury (Hg), iron (Fe), cobalt (Co) and nickel (Ni) are important environmental pollutants, particularly in areas with high anthropogenic pressure **[3]**. Their presence, also in traces within the atmosphere, soil and water, can cause serious problems for all species **[3, 9]**. One amongst the foremost significant aspects of food quality assurance is heavy metal contamination of food products **[10, 12]**. International and national food safety standards have decreased the general allowable levels of toxic metals in food products because of increased awareness of the danger of contamination of the organic phenomenon by these metals **[3]**. In developing countries, like China **[11]** and India **[13, 14]**, rapid and unorganized industrialization and urbanization have led to the elevated level of heavy metals within the urban environment **[3]**. The large amount of organic and inorganic wastes generated annually within the materials cycle and therefore the improper disposal practices used have created a worldwide problem **[6, 22]**. Heavy metal pollution is one in all the best consequences of industrializations **[24]**. Heavy metal could be a general collective term that refers to metalloids or metallic components that are toxic at low concentrations and have a comparatively high mass **[21]**. Heavy metals are widespread pollutants of great concern as they're non-degradable and are thus persistent **[28]**. Soil heavy metal contamination refers to the buildup within the soil of heavy metals **[20]**, leading to concentrations above the background values **[5]**. While heavy metals can naturally occur, **[30, 26]** suggested that numerous anthropogenic activities within the ecosystem have resulted in exceptionally high levels of heavy metals. it absolutely was stated by Rehan and Alsohim **[29]**, the amount of heavy metals within the environment has increased since historic period. Soil, groundwater, sediments, surface water, and heavy metal pollution may be a global issue **[24, 31]**. Because of the non-biodegradable nature of heavy metals, their threat is multiplied by their accumulation within the environment through organic phenomenon **[23, 6]**.

Effect of Heavy Metal on the Environment:

Industrial processes like galvanizing, steel making, leather tanning, wood preservation, ceramics, glass production and chemical manufacturing and fertilizer applications release alarmingly higher levels of heavy metals into the natural environment **[2, 15, 16, 17]**. Via their adverse effect on heterogeneous microbial communities that inhabit soils, the buildup of those heavy metals in soils can cause a decrease in soil fertility. Also, via food chains, heavy metals are known to cause toxic effects on both plant and human health **[2, 18]**.

Therefore, because of the actual fact that heavy metals move the environment which they're biologically nondestructive, An eco-friendly alternative to scrub up the polluted metal ecosystem and thus maintain the health of the declining environment has become extremely necessary **[2, 19]**.

In general, heavy metals pollution can indirectly affect the biogeochemical cycles and ocean productivity **[6, 34]**. The respiration, metabolism and activities of soil microorganisms similarly because the conversion of organic carbon to bio-carbon are adversely stricken by heavy metals within the soil. Heavy metals within the atmosphere may contribute to plant physiological dysfunction and malnutrition and may be transmitted to species at higher tropic levels, with the potential to cause great and permanent harm to human's health **[5]**. Heavy metals can accumulate in living organisms and are liable for many metabolic and physiological disorders **[32]**. Also at very low concentrations **[26]**, most heavy metals are very toxic, carcinogenic, and mutagenic. The work and activities of essential cellular components is disrupted by heavy metals **[29]**. Thanks to their bioaccumulation and non-biodegradability nature, heavy metal pollution is of great environmental concern **[4]** and represents risks to human and therefore the ecosystem **[29]**. In general, heavy metals are recalcitrant and tenacious in nature **[6]**, which makes them a major threat to organisms' environmental dominance and life **[35]**. Thanks to the adverse effects of heavy metals on the ecosystems and organisms that rely on such, there's an urgent must get obviate the environment of excessive pollution as a results of these toxic elements **[6, 33]**.

Many of them, like Zn, Cu, Co, Ni, Mn, and Fe have the nutritional characteristics called essential "trace elements" are necessary for living organisms **[41]** because at a specific concentration levels, these elements participate some enzyme activities **[7]**. The toxic effects of those dual functional ions are exposed when in excess concentrations. Since they're stable and thus permanent environmental pollutants, heavy metals cannot be degraded or killed **[42]**. By affecting the expansion, morphology and biochemical activities, heavy metals influence the microbial population and leading to decreased biomass further as diversity. Microbes have therefore evolved mechanisms to face up to metals either by efflux, complexation or reduction of metal ions within the presence of heavy metals or to use them as terminal electron acceptors in anaerobic respiration **[43]**. Most mechanism reported involves the efflux of metal ions outside the cell, and genes for tolerance mechanisms are found on both chromosomes and plasmids **[7]**. Bacteria that are immune to and grow on metals play a very important role within the biogeochemical cycling of these metal ions **[7]**.

An increasing problem for the treatment of various infectious diseases is bacterial resistance to antibiotics and other antimicrobial agents **[7]**. The connection between metal tolerance and antibiotic resistance in bacteria **[44]** is assumed to occur thanks to the likelihood that resistance genes to both (antibiotics and heavy metals) is also located closely together in bacteria on the identical plasmid **[7, 45]**. Therefore, we want to be more responsive to the drastic use of antibiotics in practice and of other antimicrobials, like heavy metals, that we bring into the planet **[7]**.

Heavy metal(s) are widespread pollutants of environmental concern as they're non degradable and thus persistent **[46, 8]**. It's well-known that every metal contains a permissible limit, beyond which they're normally dangerous and a few are even toxic **[47]**. Over one billion kinsmen are currently estimated to be exposed to high environmental concentrations of toxic metals and metalloids, and several other million people may suffer from subclinical metal poisoning **[8]**. Furthermore, the adverse effects of heavy metals include system suppression and carcinogenicity, neurotoxicity, primarily in adolescents, and inhibition of the function of some essential enzymes linked to the assembly of important biomolecules, together with the buildup of biomagnifications-causing species within the body **[48, 8]**.

Mechanism of Heavy Metal Remediation by Microorganisms:

Conventional methods like chemical oxidation, reduction, adsorption, electrolytic recovery, and so forth are rendered futile due to either financial burden or lack of ecofriendly nature in the remedial process **[8]**. Despite the best human efforts, the spread and concentration of heavy metals is still growing. In sectors such as mining, petrochemicals, and electronics, this is due to indiscriminate and harmful types of industrialization. In 1990s, a new scientific area has developed which could help to recover heavy metals using biological means, that is, biosorption at less expensive manner **[49, 8]**. The biosorption technique uses the properties of living organisms or their biomass to commercially adsorb metals **[50, 8]**. This is because of the affinity on bacterial surfaces of heavy metal hydroxylated and carboxylic functional group molecules, contributing to their adsorption and precipitation. This biosorption is passive nonmetabolic process of binding various chemicals on biomass **[51]**. The majority of biosorption metal removal studies deal with the use of either laboratory microorganisms or biomass produced by **[52]** pharmacology and food processing industries or waste water treatment units and there are only limited knowledge on the bioremediation of heavy metal contamination using halophilic microorganisms in marine and hyper saline environments **[8, 53, 54]**.

A relatively young, inexpensive and socially appropriate technology bioremediation, on the other hand requires the use of natural resources such as microbes and plants (bioremediation) to tackle heavy metal problems and subsequently restore the lost fertility of soils **[2, 59]**. Many scientists across different nations have used live or dead bacteria **[60]**, fungi **[23]**, yeast **[64]** and algae **[65]** to biosorb heavy metals among the various bioremediation options. In instinctive ecosystems, the speciation, behavior, transport and definitive fate of heavy metals relies primarily on biosorption with surface functional groups of microbial communities **[66]**. Reported that different biomass types are capable of efficiently accumulating heavy metal ions **[51]**. Bacterial biomass has been found to be one of the most effective biosorbents used for metal removal/detoxification among the various microbial populations, and thus, in recent experimental and modeling studies, the adsorption of heavy metals on bacterial cell walls has received considerable attention **[68, 69, 70]**. Studies targeting the cell surface architecture, chemical functional group recognition, and acid-base characteristics of biomass are important to predict metal biosorption behavior and adjust the property of metal biosorption in order to better understand the complex biosorption mechanism **[2]**.

Bioremediation is used using microbes **[55]** or their enzymes to clean up contaminated areas **[56]** to turn toxic heavy metals into a less dangerous state. In the revitalization of the environment, the strategy is environmentally friendly and cost efficient **[57]**.

Bioremediation of heavy metals has limitations **[4]**. The development of toxic metabolites by microbes and the non-biodegradability of heavy metals are among these. The direct use of microorganisms with distinctive catabolic potential characteristics and/or their products, such as enzymes and bio surfactants, is a novel approach to improving and enhancing their effectiveness in remediation **[58]**. Various alternatives to expand the application of microbiological techniques to heavy metal remediation have also been expected. For example, use of microbial fuel cells (MFC) has been studied to degrade recalcitrant heavy metals. Biofilm mediated bioremediation can be applied for cleaning up of heavy metal contaminated environment **[4]**.

Heavy metal tolerant Bacteria:

Microorganisms adopt different mechanisms to interact and survive within the presence of inorganic metals **[4]**. Various mechanisms employed by microbes to survive metal toxicity are biotransformation, extrusion, and use of enzymes, production of exopolysaccharide (EPS) **[80]**, and synthesis of metallothioneins. Microorganisms have evolved ingenious mechanisms of metal resistance and detoxification in response to metals within the setting **[4]**. The mechanism involves several procedures, along with electrostatic interaction, action, precipitation, redox process, and surface complexation **[4, 81]**. Metal oxidation, methylation, enzymatic decrease, metal organic complexion, metal decrease, metal ligand degradation, metal efflux pumps, demethylation, intracellular and extracellular metal sequestration are the most mechanical means of avoiding heavy metals, permeability barrier exclusion, and therefore the processing of metal chelators like metallothioneins and bio-surfactants **[82]**. Microorganisms can decontaminate metals by valence conversion, volatilization, or extracellular chemical precipitation **[4, 82]**. Thanks to the existence of anionic structures that empower microbes to connect to metal cations, microorganisms have a charge on their cell surface **[83]**. The hydroxyl, alcohol, phosphoryl, amine, carboxyl, ester, sulfhydryl, sulfonate, thioether, and thiol groups are the charged sites of microbes involved in metal adsorption **[4]**.

There are definite benefits to microbial remediation of heavy metal soil contamination, including low costs and soil structure maintenance **[5]**. Numerous microbial species, including bacteria and fungi from Bacillus **[72]**, *Pseudomonas* **[74]**, *Streptomyces*, *Aspergillus*, *Rhizopus* (Abd-Alla *et al*. 2012) and *Penicillium*, have significant removal ability **(Table 1)**.

Table 1: Metals that can be removed by different microbes (Jin, Luan, Ning, & Wang, 2018)

Microbe	Metals Which Can Be Easily Removed
Escherichia coli K-12	Hg, Cd, Pb, Cu, Ni, Zn etc.
Rhizopus arrhizus	Zn, Cu, Cd, Th
Aspergillus niger	Zn, Cu, Cr, Pb, Th, Co, Mn, Ni
Saccharomyces cerevisiae	Cu, Cd, Pb, Ag
Thiobacillus thiooxidans	Cu, Pb, Zn, Cd

As terminal electron acceptors, microbes use heavy metals and trace elements from which they obtain the required energy to detoxify metals through enzymatic and non-enzymatic processes **[1, 75]**. Bacterial cells are also capable of bioaccumulation, which is the ability to build both particulate and insoluble types of heavy metal ions and their by-products. Exopolysaccharide is the most important component in such bacterial cells with ion sequestration capability (EPS). Exopolysaccharide is mainly composed of complex high molecular weight organic macromolecules like polysaccharide along with smaller proportions of protein and uronic acid **[35]**. The bacteria are shielded by exopolysaccharide against environmental stresses such as heavy metal toxicity, drought, salinity, etc. Microorganisms such as *Agrobacterium spp*., *Xanthomonas campestris*, *Bacillus spp*., *Alcaligenes faecalis*, *Zygomonasmobilis*, *Leuconostoc*, *Pseudomonas spp*. and *Acetobacter xylinum*, have been identified as genera of EPS-producing microorganisms **[77]**. Strategies for the achievement of bacterial EPS heavy metal remediation must be focused on the use of non-neutral, negatively charged EPS (EPS packed with abundant anionic functional groups) to be integrated as an important biosorbent **[78]**.

Some commercial bacterial EPS, with the necessary anionicity, are Alginate (*Pseudomonas aeruginosa*, *Azotobacter vinelandii*), Gellan (*Sphingomonas paucimobilis*) **[1]**, Hyaluronan (*Pseudomonas aeruginosa*, *Pasteurella multocida*, **[1]** Streptococci attenuated strains), Xanthan (*Xanthomonas campestris*), Galactopol (*Pseudomonas oleovorans*) and Fucopol (Enterobacter A47) **[76]**. Processes such as biofilm processing, which are important in the biosorption and biomineralization of metal ions, are associated with exopolysaccharide production **[1, 79]**.

CONCLUSION

The current heavy metal bioremediation status reviewed during this study shows about the heavy metals and also the effects of heavy metals on Environment. To eliminate heavy metals from the environment, there are several techniques use but Bioremediation is that the most cheapest and environmental friendly thanks to to get rid of Heavy metal from the environment. Further research area must be extended on the main target of gene transfer within biofilms for heavy metal remediation. These would facilitate the event of improved techniques for the bioremediation of heavy metals within the ecosystem.

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