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Heavy Metal Bioremediation and Metallo *Bacterias*: A Systemic Review

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Abstract

Heavy metals pollution of the soils is the most challenging problem for the different ecological and environmental conditions. All the biological and organic compounds are degradable naturally but heavy metals cannot, so it leads to accumulated in the environment, which further create several problems. Excess amounts of the heavy metals in the environment has the main concern of the microbial community like structure, diversity and function, and it reduced the fertility of the agricultural soils, decreased the growth and yield of plants which are used in the food chain. Heavy metals are eliminated from the environment by plants (phytoremediation) and microbes (bioremediations). Bioremediation is a better solution for making the pollution free environment because of its advantages such as easy, simple, cost effective and efficient method. Microbes use several types of mechanisms for converting the toxic metals into less toxic using their enzymes and many types of adaptation techniques. Microbes have the capability to develop different kinds of heavy metals resistance via biosorption, precipitation, efflux mechanism, entrapment in extracellular, and reduction of heavy metals into less toxic forms. The present review article provides you with an overview of the principles of bioremediation, microorganisms of bioremediation, and strategies of bioremediation along with the future perspectives of heavy metals bioremediation by *bacterias*.

Keywords: Bioremediation; Heavy metals; Microbes; *Ex-situ; In-situ*; Bioremediation strategies.

Introduction

Since the industrial revolution, heavy metals waste has been increased faster. The toxic metals are mostly used in the industrial activities and fossil fuels consumption and they are accumulated by many ways like the food chain, leading to always harmful for the ecosystem as well as for human health, so we have to handle these types of challenges are very carefully and in a proper way so that any new problems are not created [1]. Bioremediation includes all those processes and actions that take place in order to return the natural environment altered by contaminants to its original condition [2]. It primarily uses microorganisms, fungi, green plants, or their enzymes to degrade and transform environmental contaminants into harmless or less toxic forms. It uses relatively low-cost, low-technology techniques, which generally have a high public acceptance [3]. Several metals are used as micronutrients in our body and they are used as enzymes and cofactors. Many metals are toxic for the microbial cells like mercury, cadmium, arsenic, silver, etc. This is more common that many metals are resistant to some microbial which has to be studied by plasmid technology. A lot of *bacterias* contain the genes which are responsible for the development of resistance for any specific heavy metals which are shown by engineering technology [4,5]. There are several protection mechanisms of heavy metal resistance by microbial cells [5]. These mechanisms are an extracellular barrier, extracellular sequestration, and active transport of metal ions (efflux), intracellular sequestration, and reduction of metal ions [6,7]. We know that heavy metals are harmful to our health so we have to solve this problem using the microorganisms because they have the capacity to tolerate these toxic metals by several mechanisms.

Conventional technologies like precipitation, reduction or oxidation, ion exchange, evaporation, and membrane filtration. These technologies can be used to eliminate these toxic metals from the environment, but these technologies lack efficiency and cost-effectiveness so we have to replace them by developing an effective new modern technology, which has cost-effective, easy, and more efficient [1].

In the current situation, we have two options one is plants (phytoremediation) and the other is microbes (bioremediation), both methods are efficiently eliminated heavy metals toxins from soil and water (Figure 1). These biological agents are eco-friendly and totally harmless to the environment because they can efficiently accumulate heavy metals from the contaminated sources, hence reducing the pollutant content to a safe level [8].

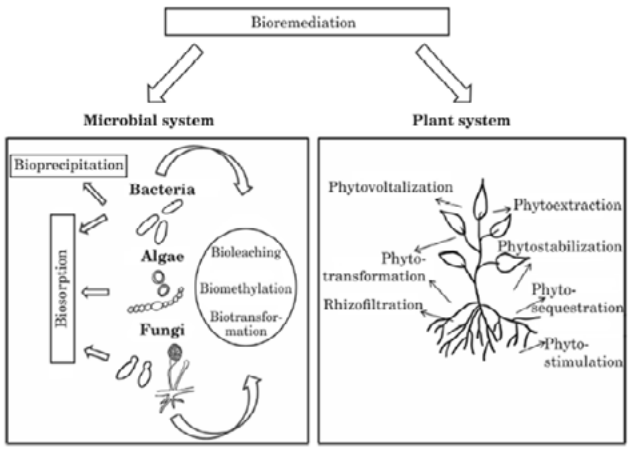

Figure 1: The two systems used for bioremediation of heavy metal (Jobby and DESAI 2017).

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Principles of Bioremediation

Bioremediation is the process whereby organic wastes are biologically degraded under controlled conditions to an innocuous state, or to levels below concentration limits established by regulatory authorities [9]. By definition, it is the use of living organisms, primarily microorganisms, to degrade the environmental contaminants into less toxic forms. Three essential components are needed for bioremediation. These three components are microorganisms, food, and nutrients. These three main components are known as the bioremediation triangle. Microorganisms are found almost everywhere on earth and nutrients are usually the missing ingredients that prevent successful bioremediation. We can find out the microorganisms in water or soil where a sufficient amount of food is available. However, if a contaminant is present it can become an additional food source for the microorganisms [10].

The contaminant serves two useful purposes for the microbes. First, the contaminant provides a source of carbon needed for growth. Second, the microbes obtain energy by breaking chemical bonds and transferring electrons away from the contaminant. This is known as an oxidation-reduction reaction. The contaminant that loses electrons is oxidized and the chemical that gains the electrons (electron acceptor) is reduced. The energy gained from the electron transfer is used along with the carbon and some electrons to produce more cells [8]. Microbes generally use oxygen as an electron acceptor but sulfate, nitrate, iron, and CO_2 are also commonly used. Most bioremediation systems are run under aerobic conditions, but running a system under anaerobic conditions may permit microbial organisms to degrade otherwise recalcitrant molecules [10].

Microorganisms used in Bioremediation

Microorganisms and plants are usually used for the removal of heavy metals. All the metals are toxic, but some of these are useful in low concentrations. This metal toxicity causes serious morbidity and mortality [11]. The bioavailability of metals is increased using the nutrients to the soil like manure, biosolids, compost, which provides suitable conditions to the soil and increases its fertility [12]. Microorganisms that carry out biodegradation in many different environments are identified as active members of microbial bioremediations (Figure 2). Bioremediation especially occurs on its own (natural attenuation or intrinsic bioremediation) or are often spurred on via the addition of fertilizers to extend the bioavailability within the medium (biostimulation) [8].

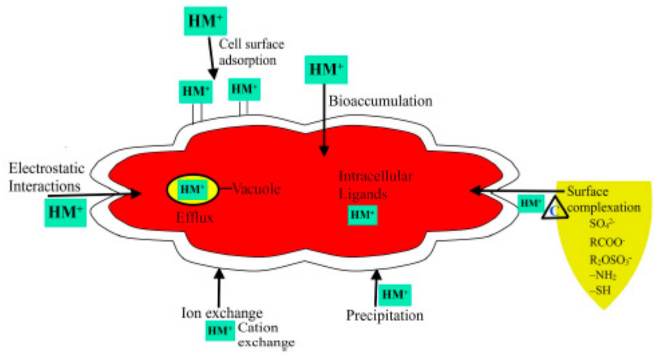

Figure 2: Mechanisms of heavy metals uptake by microorganisms (Ayangbenro and Badalona 2017).

New advancements have also proven successful by the addition of matched microbe strains to the medium to reinforce the resident microbe population's ability to interrupt down contaminants. Microorganisms used to perform the function of bioremediation are known as bioremediation (bioaugmentation), they include species of *Xanthofacter, Penicillium, Bacillus, Pseudomonas, Flavobacterium, Mycobacterium,* and *Nitrosomonas* [8]. Metallic pollutants are not degraded while composting but it may be converted into other forms like organic combinations which have less bioavailability than mineral combinations of the metals [13].

Many microorganisms can produce iron complexing molecules, named siderophores. These molecules are synthesized in the case of iron deficiency. Some of these siderophores also have high affinities for heavy metals; synthesis can also be induced by heavy metals even in the presence of high iron concentrations. A comparison between negative and constitutive siderophores mutants leads to the conclusion that siderophores or, more generally metallophones, can play a role in metal solubilisation [8]. The bacterium can solubilize metals (or increase their bioavailability) via the production of siderophores and adsorb the metals in their biomass, on metal-induced outer membrane proteins, and by precipitation. The difficult point is to find an easy way to separate the biomass, loaded with metals, from the soil matrix. The bacterium was able to improve the settling of the soil by the production of some extracellular polymers. In that way, biomass and soil could be separated more easily, for example, through settling or flotation. The heavy metal resistance, precipitation capacity, and improved soil flocculation lead to the development of a bioremediation method for heavy metal contaminated soils [14].

Bioremediation Strategies

Based on the removal of wastes for treatment there are generally two types of strategies that are available for bioremediation are *in situ* and *ex-situ* bioremediation.

In situ Bioremediation

In situ bioremediation is a subsurface application of bioremediation compared to *ex-situ* bioremediation, which includes media above the ground readily accessible (e.g., soil piles in bioreactors or in treatment cells). *In situ* bioremediation may be applied in the saturated or unsaturated soil and groundwater [8]. *In situ* bioremediation technology was originally developed as a more effective and less costly alternative to the standard pump-and-treat methods used to clean up aquifers and soils contaminated with organic chemicals (e.g., chlorinated solvents, fuel hydrocarbons), but has since widened to address explosives, toxic metals (e.g., chromium) and inorganics (e.g., nitrates). It is an important method in cleaning contaminated environments since it is cheaper and uses harmless microorganisms to degrade the chemicals. Chemo taxis is useful in the study of *in situ* bioremediation because microorganisms with chemotactic abilities can migrate into an area containing contaminants. Therefore, by enhancing the cell's chemotactic abilities, *in situ* bioremediation will become a safer method in degrading toxic compounds [10].

Ex-situ Bioremediation

Ex-situ bioremediation is a biological process were excavated soil is placed in a lined above ground treatment area and aerated following processing to facilitate the degradation of organic contaminants by the indigenous microbial population. This process requires the excavation of contaminated soil or pumping of groundwater to enhance microbial degradation [15]. *Ex-situ* bioremediation involves excavating the contaminated material and its treatment in above-ground facilities located on-site or off-site, whereas *in situ* bioremediation are undertaken at the site of contamination. *Ex-situ* methods involve extraction separation, treatment of secondary waste streams, and the proper disposal of the solid wastes. The *ex-situ* treatment processes are better understood; hence, they are relatively easy to implement, monitor, and control. The treatment of radionuclide-contaminated soils, sediments, and wastes involves excavation followed by *ex-situ* treatment or disposal. The common *ex-situ* treatment for excavated soils is solidification or stabilization [8].

Conclusion

Heavy metal toxicities are the challenging task because it is harmful to human health via interference of the vital cellular functions of the human's body. Cadmium, mercury, copper, manganese, lead, and selenites are the metals and metalloids that are widely present in the environment. P-type ATPase system is exported the cytoplasmic ions to the periplasm and efflux transporters that are further exported periplasmic ions to the outside, these are the general mechanism of resistance for heavy metals like Co, Pb, and Cd, etc. Furthermore, in the metals detoxification by sequestration, binding factors will be involved in creating tolerance to heavy metals ions. *Bacterias* are very important for the bioremediation of heavy metals and more research is required for further improvement of bioremediation of heavy metals by microorganisms.

Future Perspectives

Bioremediations is a very important strategy for solving the heavy metals ecosystem and environment pollution using the microorganisms. As we know that heavy metals toxicity is the major concern of our health issues so we have to develop a permanent solution for that via new modern technologies. We have to do further detailed studies about the heavy metals toxicity and it's a major concern so that we can identify the best way to solve it effectively. Further many types of research are required to understand the whole mechanism of heavy metals bioremediation and metals resistance in microbes.

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