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Heavy metal pollution – A mini review

Abstract

Soil contamination due to human oriented activities is an emerging issue in the present world. There are several pollutants from different industries which are released in the nearby soils. Among these pollutants, heavy metals constitute non-biodegradable, toxic and persistent pollutants which adversely affect ecological niche of all life forms, including humans. The detrimental effects of these heavy metals on living organisms are attributable to a number of cellular and biochemical processes in living organisms. In humans, these are known to cause various physiological disorders of respiratory, renal and gastrointestinal system. The biotoxicity of heavy metals depends on their concentration, chemical forms and bioavailability.

Keywords: heavy metal, chromium, bacteria, soil contamination, biotoxicity, bioavailability

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Introduction

Heavy metals are generally defined as metals required in trace amounts and considered as toxic.[1] These metals have been widely investigated by many researchers due to their significant hazardous impact on human health and environment.[2] These are considered as major source of environmental contamination due to their toxic nature and their ability to accumulate.[3] Industrialization, urbanization, and agricultural activities resulted in increase of heavy metal concentrations in different habitats compared to their natural background levels.[4]

Mobility of these heavy metals by activity of several atmospheric events e.g., runoff water and blowing winds enhanced their accumulation in the topsoil, polluting air and water that leads to chronic disorders in living bodies inhabiting these localities.[5] Street dust, roadside soil and plants growing in these polluted areas are subjected to receive high amount of heavy metals both from hazardous gases emitting from motor vehicle and transported toxic materials.[6] Vehicular activities on roads by motors also promote metal levels especially lead and nickel, in our ecosystem through burning fossil fuels and vehicle wear i.e., brakes, vehicle body, tyres and vehicular fluids.[1] Lead is the most prevalent heavy metal contaminant found in the aquatic environments and nearby soils of industrial region.[7]

Heavy metals in biological systems

Heavy metals in the Earth's crust are usually available in traces but utilized in many aspects of our daily life i.e., in golf clubs, self-cleaning ovens, cars, antiseptics, plastics, mobile phones, solar panels, particle accelerators and many others.[8] Some heavy metals in trace amounts are also required to carry out biological processes such as copper and iron are helpful in electron transport systems, cobalt used in complex synthesis and cell metabolic processes, zinc in hydroxylation, manganese and vanadium in regulation and functioning of certain enzymes, chromium used in glucose utilization, nickel is helpful in cell growth, arsenic contributes in metabolic growth of some animals, similarly selenium acts as antioxidant and hormone producing agent, molybdenum is helpful for catalytic activity of redox reactions, similarly cadmium is used by some diatoms for the similar purpose and tin is also required for better growth of some marine species.[9]

Among heavy metals, chromium, mercury, arsenic, cadmium and lead are spread widely in the environment. There are few heavy metals which are necessary for plants in trace amounts but can become hazardous if used in slightly greater amounts than the required concentration.[10] These heavy metals are a potential threat to living organisms on account of their extensive use and their toxic nature in combined or elemental forms.[11] Some heavy metals have a strong affinity for sulfur when bind via thiol group (–SH) in the body of human beings.[12] These metals usually bind with enzymes using sulfur-metal bonds which are responsible for controlling the speed of metabolic reactions.[8] These –SH bonds hinder the functioning of the enzymes involved resulting in health deterioration of affected humans which sometimes becomes lethal in prolong situations.[9] Chromium (in its hexavalent oxidation form) and arsenic are carcinogenic.[13] High doses of cadmium cause a degenerative borne disease.[1] Similarly high concentration of lead and mercury damages the CNS (central nervous system) in the human body.[3]

Phytotoxicity by heavy metals

Discharge of metal waste into air, water and soil through various industrial processes including tanning, dyeing, electroplating, printing, batteries, pigments, ceramics, glass and metallurgy, dust from old paint containing lead, use of mercury in lamps and thermometers etc. results in continuous accumulation of chromium, antimony, lead, mercury and other heavy metals in food chains which leads to biomagnification causing harm to human life.[4] This un-checked discharge of chromium in its hexavalent form into water channels has lethal effects on life quality affecting biological systems of living flora and fauna. This metal toxicity causes conformational changes by altering overall configuration of proteins, ribonucleic acids and osmotic balance of the whole body.[2] This metal toxicity is linked to direct release of industrial wastes into water channels and streams and is not limited to aquatic organisms only, but it also influence soil properties, activity of plants as primary producers, survival of animals feeding these contaminated plants and ultimately human beings. The carcinogenicity associated with heavy metal also resulted in cell impairment by inhibiting the enzyme activity of cytoplasmic organization as a result of oxidative metal stress.[6,9] Phytotoxic effects associated with heavy metal contamination on crops include chlorosis, impaired photosynthesis, impaired growth, reduction in biomass and eventually causes plant death. In the current scenario, it is essential to reduce metal uptake by heavy metal-resistant plants and limit the entry of these toxic metals into food chains which then gradually reaches upto highest trophic level.[5]

Application of metal-tolerant bacteria: An effective remediation strategy

Heavy metals along with many other pollutants can be lethal to human health as well as environment, even at low concentration due to gradual accumulation of this metal salts.[14] Therefore, remediation strategies are needed to reduce this heavy metal pollution. Toxic form of these metals can become environment friendly by changing into less toxic form through certain mechanisms either, by chelating with different chelators via physical or chemical pathways or by shifting their valence shells by redox reaction.[5] This is the basic principle of metal removing methods which utilizes microbial potential for metal removal i.e., microbial remediation. This metal removing technique is emerging as environment friendly and economical technique for the present issue of environmental pollution.[15] The mechanism of interaction of these heavy metals with microbes exhibit different toxic effects due to the divergence in bonding degree of potential ligands and the variation in mobility of each individual metal ion.[16]

Application of naturally occurring metal-tolerant bacteria, especially those which are involved in growth proliferation and known as plant growth-stimulating bacteria, is significant for the survival and stimulation of development process of treated plants under stress.[17] It is also evident that such resistant bacteria are helpful in phytoremediation of metal polluted soils contaminated with these heavy metals.[6] Such microbes are potential agents to reduce metal toxicity by modifying intrinsic properties of cells i.e., structural changes in the cell wall, production proportion of extracellular polysaccharides and their ability to coagulate or bind metals outside or inside the cell. Moreover, some microorganisms may infer resistance genes encoding highly specific tolerance mechanisms against these toxic metals.[18] These genetic determinants can be chromosomally oriented or may be located on plasmids with metal- resistance genes.[6,13] The localization of these resistance systems on either plasmids or other transportable genetic elements allows the spread of specific genes that is responsible for resistance against heavy metals among these microbial populations inhabiting polluted soils.[18] In fact, the results of several investigations revealed that elevated concentrations of these heavy metals can bring structural changes in the microbial community which in turn is linked to an increase in metal tolerance of bacterial strains.[19]

These microscopic tiny creatures have evolved specific tolerance mechanisms to cope with this metal toxicity such as reduction of metal ions, extracellular sequestration, reduced cell permeability and many others.[4] Among these detoxification mechanisms, production of siderophores is crucial as their canonical function is to scavenge insoluble iron and metal- resistant bacteria use these secreted molecules to bind with other metals thereby, reducing metal toxicity in contaminated systems.[4,13] These siderophore-metal complexes are incapable to enter into the bacterial cells, thereby reducing free toxic metal concentrations in the heavy metal polluted environment.[20] This capability suggests utility of siderophores or siderophore-producing microbes to remediate heavy metal-contaminated environments.[11] Thus, use of metal-tolerant bacteria can be an efficient strategy to reduce metal pollution in contaminated areas, thus, enabling us to use natural tools for reducing heavy metal toxicity in the environment.

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Conflict of interest

Authors declare that there is no conflict of interest.

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