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## HEAVY METALS: COTTON PLANT

BALDIWALA S<sup>1</sup>, UPADHAYAY D<sup>2</sup>, MARCHAWALA F<sup>2</sup>, ANDHARE P<sup>2</sup> AND  
BHATTACHARYA I<sup>2\*</sup>

1: Student, M. Sc. Microbiology, Parul Institute of Applied Sciences, Parul University, Post  
Limda, Waghodia, Gujarat, 391760

2: Assistant Professor, Parul Institute of Applied Sciences, Parul University, Post Limda,  
Waghodia, Gujarat, 391760

\*Corresponding Author: E Mail: Indrani Bhattacharya: E Mail: [ibd9904035346@gmail.com](mailto:ibd9904035346@gmail.com); Tel:  
+919904035346

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### ABSTRACT

Heavy metals are naturally occurring elements which have a high risk of pollution in various levels of ecosystem. Due to numerous activities of agriculture, medical, industrial and technological application have led to their wide distribution in the ecosystem, which may arise worries to many factors, which shall be taken into consideration leading to mankind and ecosystem. The toxicity may depend to many different anthropogenic unmanaged factors which increases soil pollution globally. These pollutants can be either organic (PCB's, PAH's, fertilizers and pesticides) or inorganic pollutions including various heavy metals (cd, cu, As, Zn, Hg, Pb). Classification of metals is termed as heavy metals. Heavy metals have not only been known for their high density but most importantly for their fatal/ harmful effects on the ecosystem and living organisms.

Several phytoremediation's or bioremediation and scientific studies are being handed-down which employed various bacteria and fungi to get over some condition. Therefore, due to lack of knowledge on the synergetic heavy metal resistance bacteria and fungi for heavy metal remediation. Heavy metals exposure does significant harm to the natural ecosystem leading to numerous health risks to human and plants. Some bacteria are usually toxic to the metals, there are some metal tolerant bacteria are used for bioremediation. Bioremediation can be

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said as a satisfactory technique and effective way of reclaiming habits polluted with heavy metal by making use of the biological process of microorganism and plants to remove dangerous pollutants.

**Keyword: Copper sulphate, zinc sulphate, toxic effects and ecosystem**

## INTRODUCTION

Heavy metals pollution is a severe concern due to its hazardous influence at very small concentrations. Heavy metals are non-biodegradable, also cause bioaccumulation in tissue of different levels of organism are biomagnified along with the tropic levels. In past few years, there is been hike in ecological and global public health concern related with environment contamination by these heavy metals [1].

The expansion in population, urbanization, and industrialization, associated with the rapid growth of buildings as a result of scanty/poor planning, have caused an increase in the production of waste-management without proper disposal systems [2]. Increasing artificer mining activities, illegal refining, using of leaded petrol, airborne dust, irrational dumping, and burning of toxic waste, absorption of production industries in inhabited areas, as well as weak and insufficient environmental legislation, have all given rise to the inimitable heavy metal pollution in past few years [2]. Their indication is found into different levels rivers, soil, water, and atmosphere which can be serious cause for many health problems. Because of the industrial revolution and economic/fruitful

globalization, the diversity of ecosystem contaminants has increased tremendously, with unlimited anthropogenic sources [2]. Thus, the diverse and emerging issues of food security have become a global hindrance, particularly their indissolubly association with human health [4]. International and national food safety standard have decreased the overall allowable levels of toxic metals in food products due to increased awareness of risk of contaminations of food chain by these metals. In particular countries like U.S., U.K., and Japan, hazardous contaminates are found in foods like heavy-metal example, arsenic, lead, cadmium, and mercury, which are tend to be controlled. additionally, the Joint FAO/WHO Expert Committee on Food Additives (JECFA) recommends calculating the provisional tolerable weekly intake (PTWI) for an individual heavy metals instead of the acceptable daily intake (ADI) comparing their pollutants levels considering and their toxicity accumulated in the human body [7].

Industrialization and technological revolution have put a heightened burden on the environment by releasing large quantities of hazardous waste, heavy metals

like cadmium, chromium, and lead and metalloids elements which serve as a median property between those of typical metals and non-metals, such as arsenic and antimony, and organic contaminants that have deliver serious damage on the ecosystem [5]. The rate of increase of heavy metals and metalloids in soils and waters continues to create critical global health concerns, as these metals and metalloids cannot be degraded into non-toxic forms, but are present in the ecosystem continuously. Contamination of the environment with heavy metals has hiked beyond the recommended limits and is destructive effects to all life form [6].

Heavy metals are naturally/spontaneously occurring elements whose atomic weight and density is greater than 5 time of that water. Heavy metals pollutants are generally referred to metalloids or metallic components which are toxic at low concentrations and have high relatively atomic weight. These metallic elements are examined as a systemic toxicant that are known to give multiple organ damage, even at alower level of exposure [8]. They are also classified as human carcinogens agents, according to the U.S. agency like, Environmental Protection Agency (EPA), and the International Agency for Research on Cancer [11]. This review evaluates an analysis of their environmental circumstances, production and usage,

potential for human exposure, and molecular technique of toxicity, genotoxicity, and carcinogenicity. It has been enlightening that metals such as cobalt (Co), copper (Cu), chromium (Cr), iron (Fe), magnesium (Mg), manganese (Mn), molybdenum (Mo), nickel (Ni), selenium (Se) and zinc (Zn) are essential nutrients that are required for many biochemical and physiological functions [9]. Limited supply of these micro-nutrients results in a variety of deficiency diseases or syndromes. Heavy metal toxicity can be both acute or chronic effects. Long-lasting exposure in the body to heavy metal can gradually lead to many crucial issues like, muscular, physical and neurological degenerative processes that are similar to some disorderliness like, Parkinson disease, multiple sclerosis, muscular dystrophy and Alzheimer disease. Also, chronic long-lasting exposure of some heavy metals may cause cancer [10]. Heavy metals are also called as “Trace Element” due to their presence in trace concentrations which can be ppb range to less than 10ppm range in the various environmental matrix [12]. Their bioavailability can impact by physical factors such as temperature, phase association, adsorption [13]. Chemical factors also influenced by thermodynamic equilibrium, complexation kinetics, lipid solubility and water partitioning coefficients [14].

Metal toxicity is a notable environmental concern because of their bioaccumulation and non-biodegradability in nature. Several microorganisms have employed to develop detoxification mechanisms to conflict the toxic effects of these inorganic metals [15]. This present analysis offers a critical evaluation of bioremediation measurements of microorganisms, especially related to the environmental protection. The bio-sorption capability with respect of using microorganism like bacteria, fungi, biofilm, algae, genetically- engineered microbes, and immobilized microbial cell are used for the removal of heavy metals toxic. The utilization of biofilm has showed synergetic effects with many folds increase in the removal of heavy metals as sustainable environmental technology in the upcoming future [16].

#### **Heavy metals a “curse”:**

Heavy metals are curse to the environment, leading its effects also to mankind, the traces of heavy metals toxin proof are found in the different cellular, metabolic, proteomic levels. In a pregnant women and children in Nigeria. However, the concentration of heavy metal pollutants in South Africa found maternal and umbilical cord blood from inhabitants of preferred areas showed intolerably high levels of mercury (Hg), lead(Pb), cadmium (Cd), and selenium(Se). Heavy metals were identified in the umbilical cord also whole blood

samples were indicating high risks of heavy metal pollution to both grown-up and foetuses. Given the prevalent heavy metal disclosure from both environmental and occupational position in developing countries, an intimate awareness of the effect of these noxious metals on mankind health is very important. Heavy metals have been investigated to effect on cellular organelles and various components such as cell membrane, mitochondria, lysosome, endoplasmic reticulum, nuclei, and various other enzymes which are involved in metabolism, detoxification, and damage repair. Metal ions have been found to be interacting with cell components like as, DNA and nuclear proteins, which causes DNA damage and conformational changes that may lead to cell cycle modulation, carcinogenesis or apoptosis.

Heavy metals are extensively used to advocate the standard of living in developed nations and they enter via environment through natural or anthropogenic sources which, include artisanal mining, illegitimate refining, inadequate/poor disposal of waste, and constant increase in industrialization and urbanization. Thus, the threat of human exposure continues to expand as a result, the prevalence of heavy metals in the environment.

Millions of people are exposed to arsenic throughout the world, mostly developing

countries like Bangladesh, India, Chile, Uruguay, Mexico, and Taiwan, where the under-ground water is contaminated with high level concentrations of arsenic. Drinking water are contaminated with arsenic which are present in various substance like, wood preservatives, herbicides, pesticides, fungicides and paints. Large-scale industrialization imparts damaging effects on soil as well as on crop production by the accumulation heavy metals. Damage like, to soil texture, likewise, pH of soil, including of different elements, and accumulation of heavy metals cause direct or indirect depletion of plant growth by adverse effects various physiological and molecular actions of plants.

Heavy metals like, Zinc, Copper, Molybdenum, Manganese, Cobalt, and Nickel are essential for critical biological processes and developmental pathways. although, these metals coupled with four other highly toxic heavy metals which include, arsenic (As), lead (Pb), cadmium (Cd), mercury (Hg), Chromium (Cr), aluminium (Al), and beryllium(Be) can reduce crop production at a great extent when their concentration are high beyond limited values given. These toxic elements can arise critical morphological abnormalities, metabolic disorders that dominance the yield reduction in plants. The essential heavy metals bring an important role in

biochemical and physiological functions in plants and animals. They are important/chief role which constituent of several key enzymes and play major roles in various oxidation-reduction reactions. Similar to copper, various other essential elements are needed for biologic working, however, an excess/high amount of such metals produces cellular and tissue damage/harm leading to a variety of disadvantageous effects and human diseases. For some including chromium and copper, and many metals. There is a very hair-line/narrow range of concentrations between beneficial and toxic effects.

Hence, due to their toxic, non-degradability nature, pollution to environment it may arise risk to ecosystem and mankind. They can be serious threat to the spices and ecosystem. Due to their adverse effects of heavy metals on the ecosystem and organism that depend on such a critical issue it's urgent to get remedies and get rid of the heavy metal toxicity. Bio-remediation is working in order to transform toxic heavy metals into a less dangerous state using microorganism or its enzymes to clear-out polluted environment. The mechanisms are environmentally friendly /eco-friendly and cost-effective in the revitalization of the environment. The toxic effects of these dual functional ions are exposed when in excess concentration. Since they are stable there can be

permanent environmental pollutants, heavy metals can be degraded or killed.

Many bacteria have particular genetic mechanisms of resistance/ tolerance to toxic metals. In the environment metals may choose these resistant variants in a manner to acquire the selection of antibiotic resistant strains. Certainly, it is relatively common the relationship of metal and antimicrobial resistance, cause both resistance genes are frequently located on the same mobile genetic elements.

#### **Mechanism of microbial detoxification of heavy metals:**

Industrial wastewater is a great source of heavy metal contamination in our ecosystem. Heavy metals are of profitable significance in industrial usage but the most important pollutants in the environment. Environmental pollutants from heavy metals have become a serious threat to living organisms in an ecosystem. Metal toxicity is a great environmental issue because of their bioaccumulation and non-biodegradability in nature.

The direct use of microorganisms with extraordinary features of catabolic potential and their by-products likewise enzymes and bio surfactant are a unique approach to strengthen and boost their bio-remediation effectiveness. Numerous substitutes have also been anticipated for wide applications on microbiological techniques towards the bio-remediation of heavy metals. For

example, employment or use of microbial fuel cell or MFC to degrade recalcitrant heavy metals has been explored. An efficient way of removing toxic metal contaminants from the environment and stabilizing the ecosystem is to make use of indigenous microbes with mechanisms capable of degrading issue like heavy metals, or genetically engineered microorganisms has been taken to treat toxic environments by converting toxic heavy metals into non-hazardous forms. However, the bioremediation process can be successful if microorganisms with manifest ability to remediate and tolerate heavy metals.

Microorganisms have essential bioremediation of heavy metal contaminated environments as they have different criteria to resist metal toxins. The utilization of microorganisms to sequester, precipitate, or change the oxidation state of various heavy metals has been widely study. Bioremediation of heavy metals will be successful if a companionship of bacterial strains are utilized rather using a single strain culture. studies of Kang et al says, the various effect of bacterial mix on the bio-remediation of a mixture of Pb, Cd and Cu from contaminated soils using four type of strains such as *Viridibacillus arenosi*, *Sporosarcina soli*, *Enterobacter cloacae* and *E. cloacae* was examined. They observed that the bacterial mix had considerable resistance and

efficiency for the remediation of heavy metals toxin in contrast by using single a strain culture after 48 hr with remediation potency of 98.3% for Pb, 85.4% for Cd and 5.6% for Cu are recorded

Yeast like *Saccharomyces cerevisiae* are used as efficient agents of remediation because they have the capability to resist toxic metals from contaminated wastewaters or sludge water by biosorption through the mechanism of ion exchange. Algae turns out to be a large biomass which gives them a high-level sorption capacity contrast to the different microbial bio-sorbents. Mustapha and Hali moon, obtained biosorption efficiency of 15.3–84.6% by using algae which is high compared to other microbial bio sorbents. This takes place by ion exchange mechanisms. It was also reported that brown marine algae effectively resist heavy metal such as Cd, Ni and Pb by chemical groups on their surfaces such as carboxyl, sulfonate, amino and sulfhydryl groups.

#### **Remediation of Heavy Metals by different microbes:**

Numerous filamentous fungi belonging to the genera *Trichoderma*, *Penicillium*, *Aspergillus*, and *Mucor* have been described as having the power to tolerate heavy metal stress. Fungal cell walls have exceptional capability for metal binding properties due to presence of negative charge on the various functional groups,

like carboxylic, amine or sulfhydryl, phosphate, in contrast wall components. A study showed interaction of *Aspergillus niger* var. *tubingensis* Ed8 with Cr (VI) helps in the reduction process and also in a sorption process Previous studies reported reduction in As induced stress in chickpea through *Trichoderma* sp.

Bacteria are the most critical microbial organisms used for the bioremediation of heavy metal contaminated soils. Bacteria help in reduction of heavy metal ion toxicity by immobilizing, mobilizing, uptake, and transformation of heavy metals. Various studies are been reported where PGPR act as potential evoke for abiotic stress tolerance including heavy metal tolerance or resistance. Heavy-metal tolerant PGPR includes strain of many different microbes like *Bacillus*, *Pseudomonas*, *Streptomyces* and *Methylo-bacterium*, which have the potential to improve growth and production of crops by reducing the detrimental effects of heavy metals. Previous study reported Cd resistant *Ochrobactrum* sp. and Pb and as resistant *Bacillus* spp. have several PGPR traits that help in bio-remediation and growth promotion of a rice cultivator. Different rhizobacteria even have been participate to take part in metal accumulation and helps hyper accumulating plants in uptake of heavy metals and their tolerance.

In spite of those practices, nowadays, the utilization of genetically-engineered bacteria are used as a heavy metal bioremediation is acquired great consideration; however, this are limited to laboratory trials only. Genetically transformed bacteria have more than one gene which increase remediation of heavy metals. Genes act as a metal chelation, metal homeostasis, transportor, biodegradative enzymes, metal uptake regulators, and biotic and abiotic stress tolerance which is an important prospective for creating recombinant bacteria.

One such technique is the use of plant growth promoting microbes for bioremediation of heavy metal polluted soil and is a quite important factor for global climate change, also wide fertilizer usage in agricultural soil. Microbes is known for strengthening of plant growth, survival and production yield, under heavy metal stress condition as they have the ability of consuming waste and convert them from complex waste into simple non-toxic by products. This is feasible because microorganisms have developed many tolerant mechanisms for remaining present with in the toxic heavy metal environment. Microbes also strengthen bioavailability for metals from soil by chelation, acidification, and precipitation for example, organic acids released by microbes and plant roots lower

the soil pH and helps in sequestration of metal ions.

Plant breeding and genetic-splicing may be a labour intensive and time-consuming process, there a necessity to develop newer strategies or techniques that will be helpful for sustained crop production and productivity under heavy metal stress. Plant-related microbes can also be used as an alternative strategy for sustainable agricultural-production. Couple plant-associated microbes specially, bacteria and fungi are cared for exhibiting plant-growth promoting traits under the influence of heavy metal stress. These microbes impart favourable effects on plants via several direct and indirect mechanisms like biofilm formation, siderophores, exopolysaccharide, and phytohormones production. Since microbial heavy metal bioremediation doesn't associate any transgenic modifications, it is ethically and socially sustainable. While heavy metal tolerance in plants with microbial remediation has been examined for many years, they are continuing to be in interest in extensive studies on plant-microbe-metal association, that directly effects on strengthen biomass production and heavy metal tolerance.

There are several reports on the technique of biofilms are given for the removal of heavy metals. Biofilm acts as a skilled bioremediation tool as well as biological

stabilization agent. Biofilms have very high resistance against toxic inorganic elements even at a noxious concentration. A study on yeast spices, *Rhodotorula mucilaginosa* has strong efficiency to remove metal which is 4.79 to 10.25 % and for planktonic cells and from 91.71 to 95.39 % for biofilm cells. Biofilm's mechanisms can only be achieved by the remediation that could be either via bio-sorbent or by an exopolymeric substances present in biofilms which have specialized molecules with surfactant or emulsifier properties.

The bio-remediation employ different sources which include many different microorganisms, plant growth promoter test and biofilm which can help in reduction of bio-accumulation of heavy metals in different sources like water, soil, and atmosphere and also it can benefit many different concerns related to environmental pollution due to heavy metals.

## CONCLUSION

Heavy metals and contamination with bioremediations have given an exposure to many issues. Upcoming-days, studies with many remediations can help in the solving critical issue which has threaten the organism and ecosystem. A balance environment is need for every living being with nature that ensures us to sustain on this planet. Also ensure to improve the techniques which are given or which is going to come in near future. However, it is

a difficult task to monitor environment impact due to insufficient information, thus this highlights the importance of a consistent link between research and development for the evaluation and treatment of arising metal pollution and the tools, equipment and knowhow that devote toward the fulfilment of these challenges.

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## REFERENCES

- [1] Fergusson JE, editor, *The Heavy Elements: Chemistry, Environmental Impact and Health Effects*. 1990, Oxford: Pergamon Press. [Google Scholar]
- [2] Bradl H, editor, *Heavy Metals in the Environment: Origin, Interaction and Remediation*: Academic Press volume 6 London, 2002. [Google Scholar]
- [3] Gaur N., Flora G., Yadav M., Tiwari A, A review with recent advancements on bioremediation-based abolition of heavy metals. *Environ. Sci. Process. Impacts*.16: 2014, 180–193. doi:10.1039/C3EM00491K. [PubMed] [CrossRef] [Google Scholar]

- [4] WHO/FAO/IAEA. *World Health Organization*. Switzerland: Geneva, Trace Elements in Human Nutrition and Health. 1996.[Google Scholar]
- [5] Dixit R., Malaviya D., Pandiyan K., Singh U.B., Sahu A., Shukla R., Singh B.P., Rai J.P., Sharma P.K., Lade H, Bioremediation of heavy metals from soil and aquatic environment: An overview of principles and criteria of fundamental processes. *Sustainability*. 7:2, 2015, 189–2212. doi:10.3390/su7022189. [CrossRef] [Google Scholar].
- [6] Tak H.I., Ahmad F., Babalola O.O, Advances in the application of plant growth-promoting rhizobacteria in phytoremediation of heavy metals. *Reviews of Environmental Contamination and Toxicology*. Springer; New York, NY, USA. pp.2013, 33–52. [PubMed].
- [7] WHO/FAO/IAEA. *World Health Organization*. Switzerland: Geneva, Trace Elements in Human Nutrition and Health, 1996. [Google Scholar].
- [8] Fasinu P, Orisakwe O, Heavy metal pollution in sub-Saharan Africa and possible implications in cancer epidemiology, 2013, *Asian Pac J Cancer Prev*. 14(6): 3393-402. [PubMed].
- [9] Yabe J, Ishizuka M, Umemura, Current levels of heavy metal pollution in Africa. 2010 Oct, *J Vet Med Sci*. 72(10):1257-63.
- [10] Hughes JP, Polissar L, Van Belle G, Evaluation and synthesis of health effects studies of communities surrounding arsenic producing industries. *Int J Epidemiol*.17:1988, 407–413.
- [11] Jarup L, Hazards of heavy metal contamination. *British Medical Bulletin*. 68(1): 2003, 167-182
- [12] Kabata- Pendia A 3<sup>rd</sup>, editor, *Trace Elements in Soils and Plants*. Boca Raton, FL: CRC Press.2001, [Google Scholar]
- [13] Hamelink JL, Landrum PF, Harold BL, William BH, editors, *Bioavailability: Physical, Chemical, and Biological Interactions*. Boca Raton, FL: CRC Press Inc.1994. [Google Scholar]
- [14] R. K. Gautam, S. Soni, and M. C. Chattopadhyaya, “Functionalized magnetic nanoparticles for environmental remediation,” *Handbook of Research on Diverse Applications of Nanotechnology in Biomedicine, Chemistry, and Engineering*, pp. 518–551.2014, View at: Publisher Site | Google Scholar

- [15] W. L. Wai, N. A. K. Kyaw, and N. H. N. Nway, "Biosorption of Lead (Pb<sup>2+</sup>) by using *Chlorella vulgaris*," in *Proceedings of the International Conference on Chemical engineering and its applications (ICCEA)*, Bangkok (Thailand), 2012,.
- [16] K. Hryniewicz and C. Baum, "Application of microorganisms in bioremediation of environment from heavy metals," *Environmental Deterioration and Human Health: Natural and Anthropogenic Determinants*, 2014, pp. 215–227. View at: Google Scholar
- [17] Röllin HB, Rudge CV, Thomassen Y, Mathee A, Odland JØ, J *Environ Moni*, Levels of toxic and essential metals in maternal and umbilical cord blood from selected areas of South Africa--results of a pilot study. *11(3):2009 Mar*, 618-27. [PubMed] [Ref list]
- [18] Wang S, Shi X, Molecular mechanisms of metal toxicity and carcinogenesis. *Mol Cell Biochem*. *222(1-2):2001 Jun*, 3-9. [PubMed] [Ref list]
- [19] Chang LW, Magos L, Suzuki T, editors, *Toxicology of Metals*. Boca Raton. FL, USA: CRC Press, 1996. [Google Scholar].
- [20] Beyersmann D, Hartwig A, Carcinogenic metal compounds: recent insight into molecular and cellular mechanisms. *Arch Toxicol*. *82(8): 2008 Aug*, 493-512. [PubMed] [Ref list]
- [21] Tchounwou PB, Wilson B, Ishaque A, Important considerations in the development of public health advisories for arsenic and arsenic-containing compounds in drinking water. *Rev Environ Health*. *14(4):1999 Oct-Dec*, 211-29. [PubMed] [Ref list]