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DIFFERENT APPROACHES FOR BIOREMEDIATION OF HEAVY METALS – A REVIEW

Sahu T[1,]Karmakar D[2]

[1,2]Kalinga Institute of Industrial Technology.

***Corresponding Author:** **TriparnaSahu, Email ID**: tripanasa@gmail.com

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ABSTRACT

Soil is the essence of existence beyond measure. Owing to precipitous urbanization and industrialization, numerous organic and inorganic pollutants are contaminating it, it has contributed to intensified contamination of heavy metals and radionuclides into the setting. Remediation is the primary remedy for addressing the problem. There is a vital need to sprout a robust soil security program focused on the lawfully enforced precautionary, diagnostic and therapeutic instruments. Restrictive and clean-up steps to prevent polluted surface hazards are a part of the safety of the curative surface. Bioremediation is a process that utilizes natural micro-flora or has incorporated different microorganisms to assist in pollutant biodegradation and soil and groundwater regeneration. There are still several limitations that should be resolved to effectively use their system as a device for remediating polluted soils. When utilizing microbiological approaches to extract complicated polymers in the less hazardous types are regarded as biodegradation and used as an energy source for them in effect.

Key word: Heavy metal, Bio-augmentation, Remediation, Phytostabilization, Biostimulation**.**

INTRODUCTION

Soil is a single habitat that includes a wide range of microflora and fauna it gives higher plants mechanical and nutrient assistance. In sectors such as garment, clothing, cloth, electroplating, chrome plating, petroleum mining, painting, automotive industry, heavy metals are commonly used. This factories dump to the atmosphere vast amounts of hazardous waste and untreated effluents which inflict serious ecological pollution **[1]**. The question over the existence, accumulation and maintenance of organic compounds in the atmosphere induces pollution of the land, water, and air.

Metals dumped into the water sources, experiencing chemical degradation and generating larger environmental and public health effects **[2]**.

Pollution of the soil by the heavy metals is the main environmental issue which has major impacts on the biodiversity. The accumulation of heavy metals in the soil then reaches the human food by plants and induces danger and continues to move from one to another food chain. Via anthropogenic operations, the factories discharge a number of heavy metals such as chromium,cadmium,nickle,arsenic,lead, heavy metal mercury in trace quantities, which cause flora and fauna toxicity **[3]**.

Nowadays, various new technologies have been established which prioritize pollutant destruction instead of traditional disposal approach.In the goal range, many drainage techniques have been used to reduce the concentration of harmful substances in drainage from higher to lower levels **[4]**.

Atomic, visual degradation,chemical degradation and microbial degradation have remedied the soil pollution. Such approaches have certain drawbacks of fully remediating polluted land from hydrocarbons and causing more harmful to the atmosphere **[5].**

Biological therapy is one of the safest options to remediate polluted heavy metal soil, use natural microorganisms in the soil and remediating heavy metals into harmless substances **(Table 1).**

Physical,chemical and biological techniques can decontaminate polluted metal soil. These can be divided into two groups **(Table 2) [6].**

Ex situ method-

Ex situ process used to remediate the polluted soil. This needs a polluted soil for the remediation of physical and chemical pollutants by detoxification or destruction and excavation. Consequently, the contaminant is stabilised, solidified and immobilized.

In situ method-

For the removal or transformation of pollutants, Reed et al. (1992) described as the In situ approach is used. Contamination separation and bioavailability are reduced by immobilization . , Physico-chemical soil remediation methods make plant growth possible and eradicate all biological processes and microbes like nitrogen fixing bacteria,fauna and Fungi. **[7].**

Phytoremediation-

Phytoremediation is a form of remediation using plants to detoxify or eliminate toxins in the atmosphere **[8]**. The following techniques include phytoremediation, such as, phytostabilization, phytoextraction, phytotransformation, rhizofiltration , phytovolatilization, **[8].**

Phytostabilization-

Plants are grown in the field to maintain the soil and to reduce metal bioavailability. In this situation, plants need to be metal resistant, and accumulation may have become environmentally disadvantageous **[9].** Plants root from a polluted soil or solution, and remove the metals by extracting the whole plant. The translocation and tolerance are completely insignificant in this case **[9].**

Phytoextraction

It is possible to cultivate plants on polluted land, and harvest the aerial plants. In this situation, plants only need to be tolerant if the soil metal content is very higher, but in their aerial sections they need to accumulate very higher concentrations and in practice they need to be super accumulators.

Many techniques are now being used for extracting heavy metals for a few days. This involves chemical precipitation, electrochemical therapy, ion exchange, membrane processing, activated carbon adsorption, and so on **[10].**

Every each of these has its own pros and cons (Table 3). Electrochemical treatment and Chemical precipitation methods among these are more ineffective when the concentration of metal ions is small. Processes of activated carbon adsorption and ion exchange are considerably more costly than other approaches. Bioremediation has been aimed at extracting heavy metals from waste water [**3**].

Bioremediation Techniques

Bioremediation is a mechanism used in the atmosphere to detoxify or eliminate the inorganic and organic xenobiotics. Remediation process is the solution to the heavy metal pollution issue **[17]** Function of Bioremediation's principal is to reduce the cost. Bioremediation is only successful when environmental conditions permit growth and development of micro-organism, frequently involving alteration of the atmosphere and micro-organism growth **[11].**

A crucial role is played by micro-organism in the bioremediation of the waste water and polluted soil from heavy metals. But when bacteria in particular are exposed to higher metal concentration, microorganisms can have cidal effect upon them. Interaction of Microorganisms can be with metals and radionuclides through several mechanisms, some of which may serve as the basis for potential strategies for bioremediation **[13]** Processes by which microorganisms operate on heavy metals involve Biosorption , bioleaching , bio-mineralization and intracellular aggregation and enzyme pet **[12].**

Biostimulation

Biostimulation is a bioremediation and is often used to fix polluted soil. This involves incorporating nutrients, whether organic or inorganic, to promote microbial development.Care of these origins of carbon as N and P. This includes biodegradation stimulation, and these have also been calculated as C / N ratios **[24].**

In polluted soil, carbon sources are applied as a resource to improve the rate of pollutant degradation by promoting the development of microorganisms that are responsible for pollutant biodegradation.In addition to promoting the development of microorganisms, the introduction of carbon in the form of pyruvate often includes the risk of PAH depletion **[15].**

When utilizing the main composting bioremediation, the main compost materials is combined with the polluted dirt, the toxins became absorbed in the mixture by the active micro flora **[14].**

Bioaugmentation-

Under this method, the incorporation of microorganism holds the ability for biodegradation to support the indigenous bacteria in the polluted climate.It will also include introducing genetically modified microorganisms that are ideal for biodegrading heavy metal pollutants.The successful and low-cost bioremediation technique is bio augmentation in which an appropriate bacterial isolates or microbial alliance are applied to polluted sites capable of destroying xenobiotics **[16].** Various authors have documented the bioremediation of soil pollution with heavy metal sources through bio-augmentation **(Table 4).**

The ecosystem is quite complex, the degradation potential of exogenously introduced microorganisms appears to be influenced by the underlying soil's physicochemical and biological characteristics. Bio-augmentation is not an appropriate option for the remediation of polluted soil since microorganisms seldom develop in laboratory stains and biodegrade xenobiotics relative to endogenous microbes in certain instances **[17].**

Factors Affecting Biosorption-

The key influences influencing the cycle of Biosorption are (1) the initial concentration of metal ions, (2) the pH (3) temperature (4) concentration of biomass in solution.Aksu et al. (1992) stated that the Biosorption process is not influenced by temperature in the range of 200 to 300 C. In Biosorption systems, though, pH tends to be the most critical parameter.This influences the functional group solution chemistry in the biomass and the interaction of the metallic ions **[18].** The concentration of biomass in the solution tends to affect the particular take-up for lesser concentration values of biomass contributes to conflict between the binding sites.

Advantages of Biosorption-

- No-Living cells are less responsive to the concentration of ions (toxicity)
- Can be run at ambient pH conditions and temperature.
- Faible operating costs

- Chemical or biological sludge volumes should be minimized
- Nutrient supply is not needed
- Dead biomass from industrial sources can also be procured as a waste product from the fermentation processes.

Developments in Molecular Microbial Ecology-

Our current knowledge is to bring about improvements in microbial communities during a phase of bioremediation is very small, and thus the microbial community is still regarded as a "black box" **[19].**It is mainly due to the fact that modern laboratory methods still cannot cultivate many environmental bacteria **[20].** Since the bioremediation also faces the task of defining the cause and implementing actions.

Now a few days, the recent developments in the field of molecular biological methods are helping us to research the structure and dynamics of cultivation-free microbial communities. Such molecular biological techniques are often used in ecological studies involving microbial.

Table 1. Sources of Discharge of Metals

Heavy metals	Source
Nickle	Galvanized devices for storing batteries, paints and powders.
Lead	Present in petro-products based and several other manufacturing facilities
Zinc	Widely used in the manufacture of paint, rubber, dye, wood preservatives and ointments and galvanizing industries.
Chromium	Constructed operations including chrome plating, oil refining, leather, tanning, wood preservation, garment manufacturing and pulp processing. This occurs both in hexavalent form and in invalent form.
[40]	

Table.2 Harmful Effects

Heavy metal	**Effect**
Nickel	vomiting and nausea . it combine with other compounds to form zinc; specific zinc compounds contained in hazardous waste sites include zinc oxide, zinc chloride, zinc sulphate, zinc phosphate, zinc cyanide and zinc sulphide
Chromium	Irritant, vomiting and nausea, carcinogenic, exposure to low levels can irritate the skin and cause ulceration. Long-term exposure can cause damage to the kidneys and liver, and damage to too much circulatory and nerve tissue.
Lead	Damage of Nervous system, damage of circulatory system , blood production system, reproductive system, gastrointestinal tract and damage of kidney. Lead is known for its adverse impact on the living environment, reaches the body by inhalation and chewing, or skin-inclusion. The biggest danger from lead is its leaning to accumulate within the human body. The central nervous system is most discerning about the effects of lead.
Zinc	Nausea and vomiting Zinc combines with other elements to form zinc compounds; common zinc compounds found at hazardous waste sites include zinc chloride, zinc oxide, zinc sulphate, zinc phosphate, zinc cyanide, and zinc sulphide
[40]	

Table.3 Advantages and Disadvantages of Phytoremediation.

Advantages	Disadvantage
Bendable against different organic and inorganic compounds	Restricted to sites with trivial pollution within remediative plant rooting areas.
Reduces the amount of waste to be mixed with soil (up to 95 percent) and can be used as a heavy metal bio-ore.	Harvested phytoremediated plant biomass can be listed as a hazardous waste, therefore disposal should be sufficient
Applications in situ decrease contaminant spread through air and water	Climatic states are a limitation
Insitu / Exsitu application is possible with the respective effluent / soil substratum.	This can take up to several years for a polluted site to be remedied.
In situ applications the volume of soil disorder decreases in comparison with traditional methods	Reserved for sites with poor absorption of pollutants
Required no costly equipment or extremely specialized personnel	Non-native species introduction will affect bio mixture
The latent energy contained in large-scale systems may be used to produce thermal energy	The use / operation of polluted biomass from plants is a matter of concern.
comparatively low cost	elongated remediation moment

Table.4 List of Metal Degrading Microorganisms

Metal	Degrading microorganism	References
Ni	*Bacillus subtilis,* P. licheniformis	[25]
Au	*Aspergillusniger* *Chlorella pyrenoidosa*	[26] [27]
Cu	*Cardidatropicalis* *Bacillus licheniformis*	[28] [29]
Hg	*Penicillumchrysogenum*	[30]
Pb	*Penicillumchrysogenum*	[21]
Th	*Sacchromycescerevisiae*	[32]
Zn	*Rhizopusarrhizus* *Penicilliumchrysogenum* *Penicillumspinulosum*	[33] [34] [35]
Cr	*Pseudomonas aeruginosa, Bacillus subtilis, Sacchromycescerevisiae*	[36]
Cd	*Alcaligenessp, Psedomonassp, Moraxella sp*	[37]
Ag	*Streptomyces noursei*	[28]
Co	*Sacchromycescerevisiae*	[38]
Fe	*Bacillus subtilis*	[29]
Mn	*Bacillus licheniformis*	[29]

The following method (1) fluorescence in situ hybridization (FISH) with rRNA-targeted oligonucleotide probes **[21]** and (2) in situ PCR **[22]** was used to research and in situ bioremediation method for the identification and monitoring of target bacteria. the PCR amplified 16s rDNA fragments by denaturing gradient gel electrophoresis (DGGE) has identified as a important technique for tracking variations in bacterial diversity [39].Another tool for researching microbial population diversity is terminal fragment-length polymorphism (T-RFLP) restriction **[23].**

Conclusion:

To sum up, Bioremediation is to become an evolving technology that needs to establish the boundaries between promise and reality.This also tackles multiphase, heterogeneous ecosystems (i.e., soils), and bioremediation relies on an interdisciplinary approach including such disciplines as microbiology, ecology, engineering, geology, and chemistry. Due to the difficulty encountered in the nature and degree of pollution and the social and legal issues related to most polluted sites, the interdisciplinary approach often is needed.

By improving understanding of microorganisms 'ecology, physiology, evolution, biochemistry and genetics, the

prospect is effectively stimulating and harnessing microbial metabolism for environmental purposes. Despite its limitations, the potential of bioremediation appears bright as the advances which form bioremediation in the diverse disciples.Progress in designing methods for in situ microbial metal remediation approaches obviously lagged well behind the progress of organic in situ bioremediation.

However, and since financing incentives for research on in situ metal bioremediation have increased dramatically in recent years, it seems likely that novel developments will be forthcoming in this field.

- Can be run at ambient temperature and pH conditions.
- Small cost of operation
- Chemical or biological sludge volumes should be minimized
- Nutrient supply is not needed

Dead biomass from industrial sources can also be procured as a waste product from the fermentation processes.

References:

[1] Wang, J. L. (2002). Immobilization techniques for biocatalysts and water pollution control.

[2] Meenambigai, P., Vijayaraghavan, R., Gowri, R. S., Rajarajeswari, P., &Prabhavathi, P. (2016). Biodegradation of heavy metals–a Review. *Int. J. Curr. Microbiol. App. Sci*, *5*(4), 375-383.

[3] Das, N., Vimala, R., &Karthika, P. (2008). Biosorption of heavy metals–an overview.

[4] Verma, N., &Rehal, R. (1996). Removal of Chromium by AlbiziaLebbeck Pods from Industrial Waste Water. *Journal of Industrial Pollution Control*, *12*, 55-59.

[5] Garbisu, C., &Alkorta, I. (2003). Basic concepts on heavy metal soil bioremediation. *ejmp&ep (European Journal of Mineral Processing and Environmental Protection)*, *3*(1), 58-66.

[6] Shaw, J. (1989). *Heavy metal tolerance in plants: evolutionary aspects*. CRC press.

[7] Meenambigai, P., Vijayaraghavan, R., Gowri, R. S., Rajarajeswari, P., &Prabhavathi, P. (2016). Biodegradation of heavy metals–a Review. *Int. J. Curr. Microbiol. App. Sci*, *5*(4), 375-383.

[8] Ghosh, M., & Singh, S. P. (2005). A review on phytoremediation of heavy metals and utilization of it's by products. *Asian J Energy Environ*, *6*(4), 18.

[9] Latha, M. R., Indirani, R., &Kamaraj, S. (2004). Bioremediation of polluted soils–A review. *Agricultural Reviews*, *25*(4), 252-266.

[10] Matheickal, J. T., & Yu, Q. (1999). Biosorption of lead (II) and copper (II) from aqueous solutions by pre-treated biomass of Australian marine algae. *Bioresource technology*, *69*(3), 223-229.

[11] Abioye, O. P. (2011). Biological remediation of hydrocarbon and heavy metals contaminated soil. *Soil contamination*, *7*, 127-142.

[12] Lloyd, J. R. (2002). Bioremediation of metals; the application of micro-organisms that make and break minerals. *interactions*, *2*, M2.

[13] Atlas, R. M., &Philp, J. (2005). *Bioremediation. Applied microbial solutions for real-world environmental cleanup*. ASM press.

[14] Semple, K. T., Reid, B. J., &Fermor, T. R. (2001). Impact of composting strategies on the treatment of soils contaminated with organic pollutants. *Environmental pollution*, *112*(2), 269-283.

[15] Lee, K., Park, J. W., &Ahn, I. S. (2003). Effect of additional carbon source on naphthalene biodegradation by Pseudomonas putida G7. *Journal of Hazardous Materials*, *105*(1-3), 157-167.

[16] Gentry, T., Rensing, C., & Pepper, I. A. N. (2004). New approaches for bioaugmentation as a remediation technology. *Critical reviews in environmental science and technology*, *34*(5), 447-494.

[17] Abioye, O. P. (2011). Biological remediation of hydrocarbon and heavy metals contaminated soil. *Soil contamination*, *7*, 127-142.

[18] Veglio, F., &Beolchini, F. (1997). Removal of metals by biosorption: a review. *Hydrometallurgy*, *44*(3), 301-316.

[19] Iwamoto, T., &Nasu, M. (2001). Current bioremediation practice and perspective. *Journal of bioscience and bioengineering*, *92*(1), 1-8.

[20] Kogure, K., Simidu, U., &Taga, N. (1979). A tentative direct microscopic method for counting living marine bacteria. *Canadian Journal of Microbiology*, *25*(3), 415-420.

[21] Hahn, D., Amann, R. I., Ludwig, W., Akkermans, A. D., &Schleifer, K. H. (1992). Detection of micro-organisms in soil after in situ hybridization with rRNA-targeted, fluorescently labelled oligonucleotides. *Microbiology*, *138*(5), 879-887.

[22] Hodson, R. E., Dustman, W. A., GarG, R. P., & Moran, M. A. (1995). In situ PCR for visualization of microscale distribution of specific genes and gene products in prokaryotic communities. *Appl. Environ. Microbiol.*, *61*(11), 4074-4082.

[23] Liu, W. T. Marsh. TL, Cheng, H and Forney. LJ 1997. Characterization of microbiaol diversity by determining terminal restriction fragment length polymorphisms of genes encoding 16S rRNA. *Applied and Environmental Microbiology*, *63*, 4516-4522.

[24] Lee, S. H., Lee, S., Kim, D. Y., & Kim, J. G. (2007). Degradation characteristics of waste lubricants under different nutrient conditions. *Journal of hazardous materials*, *143*(1-2), 65-72.

[25] Holan, Z. R., &Volesky, B. (1994). Biosorption of lead and nickel by biomass of marine algae. *Biotechnology and bioengineering*, *43*(11), 1001-1009.

[26] Kuyucak, N., &Volesky, B. (1988). Recovery of cobalt by a new biosorbent. *Can. Min. Metall. Bull.*, *81*(910), 95-99.

[27] Darnall, D. W., Greene, B., &Gardea-Torresday, J. (1988). Gold binding to algae. *Biohydrometallurgy, Science and Technology Letters, Kew, Surrey, UK*, *487*.

[28] Mattuschka, B., &Straube, G. (1993). Biosorption of metals by a waste biomass. *Journal of Chemical Technology & Biotechnology*, *58*(1), 57-63.

[29] Beveridge, T. J. (1986). The immobilization of soluble metals by bacterial walls. In *Biotechnology and bioengineering symposium* (No. 16, pp. 127-139).

[30] Nemec, P., Prochazka, H., Stamberg, K., Katzer, J., Stamberg, J., Jilek, R., &Hulak, P. (1977). *U.S. Patent No. 4,021,368*. Washington, DC: U.S. Patent and Trademark Office.

[31] Niu, H., Xu, X. S., Wang, J. H., &Volesky, B. (1993). Removal of lead from aqueous solutions by Penicillium biomass. *Biotechnology and Bioengineering*, *42*(6), 785-787.

[32] Brierley, J. A., Goyak, G. M., &Brierley, C. L. (1986). Considerations for commercial use of natural products for metals recovery. In *Immobilization of ions by biosorption* (p. 105). Ellis HorwoodChichester, UK.

[33] Tobin, J. M., Cooper, D. G., & Neufeld, R. J. (1984). Uptake of metal ions by Rhizopusarrhizus biomass. *Appl. Environ. Microbiol.*, *47*(4), 821-824.

[34] Niu, H., Xu, X. S., Wang, J. H., &Volesky, B. (1993). Removal of lead from aqueous solutions by Penicillium biomass. *Biotechnology and Bioengineering*, *42*(6), 785-787.

[35] Townsley, C. C. (1986). Biorecovery of metallic residues from various industrial effluents using filamentous fungi. *Process Metal*, *4*, 279-289.

[36] Fathima Benazir, J., Suganthi, R., Rajvel, D., PadminiPooja, M., Mathitumilan, B. 2010. Bioremediation of chromium in tannery effluent by microbial consortia. *African J. Biotechnol.,* 9(21): 3140–3143.

[37] Springael, D. I. R. K., Diels, L. U. D. O., Hooyberghs, L. I. L. I. A. N. E., Kreps, S. A. B. I. N. E., &Mergeay, M. (1993). Construction and characterization of heavy metal-resistant haloaromatic-degrading Alcaligeneseutrophus strains. *Appl. Environ. Microbiol.*, *59*(1), 334-339.

[38] Brady, D., Duncan, J.R. 1993. Bioaccumulation of metal cations by *Sacchromycescerevisiae.* BioHydroMetallurgical Technologies; Torma A.E., Apel, M.L., 2: 711–724.

[39] Muyzer. (1993). G, de Waal EC, Uitterlinden AG. *Profiling of complex microbial populations by denaturing gradient gel electrophoresis analysis of polymerase chain reaction amplified genes coding for 16S rRNA. Applied and Environ mental Microbiology*, *59*, 695-700.

[40] Joshi, N., &Goyal, D. G. (2007). *Biosorption of heavy metals* (Doctoral dissertation)