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Unconventional Plant-based Remediation Technologies for Soil pollution at Contaminated Sites in Bhopal

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***Abstract:** The purpose of this study was to emphasize the Vegetation-enhanced bioremediation or phytoremediation plan for the surroundings of industrial area of Bhopal. This regions contain many industries and therefore there is a big risk of environmental pollution which is very hazardous to our health.Heavy metal accumulation in agricultural soils is potentially hazardous to human and livestock health. Excessive accumulations also present the risks of elevated heavy metal uptake by crops which could affect food quality and safety. Conventional remediation technologies are used to clean the vast majority of metal-polluted sites but they also tend to be clumsy, costly, and disruptive to the surrounding environment. In contrast, plants are known to sequester certain metal elements in their tissues and may prove useful in the removal of metals from contaminated soils. Over the past decade there has been increasing interest for the development of plant-based remediation technologies which have the potential to be low-cost, low-impact, visually benign, & environmentally sound, a concept called phytoremediation. Efforts should be made for dense vegetation of heavy metal bioaccumulation plants at the industrially contaminated sites. So that they reduce pollution and also give eco friendly aesthetic sense to enhance the beauty of the Bhopal city.Growing and, in some cases, harvesting plants on a contaminated site must be compulsory condition to setup or run a specific industry because this remediation method is an aesthetically pleasing, solar-energy driven, passive technique that can be used to clean up sites with shallow, low to moderate levels of contamination. This technique can be used along with or, in some cases, in place of mechanical cleanup methods.*

This paper attempted to provide a brief review on recent progresses in research and practical applications of phytoremediation for soil. Numerous plant species have been identified and tested for their traits in the uptake and accumulation of different heavy metals. Mechanisms of metal uptake at whole plant and cellular levels have been investigated. Progresses have been made in the mechanistic and practical application aspects of phytoremediation. They were reviewed and reported in this paper

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Index Terms— *Phytoremediation, Heavy Metals, Soil pollution, Contaminated Site, Phytoextraction, Rhizofiltration, phytostabilization, phytovolatilization,*

I. INTRODUCTION

Bhopal city and nearby regions are one of the most important industrial hub in the country. These regions contain many industries which are engaged in producing cotton textile, jute and electrical products. Power generation is also very important to this city. The industry related to the production of electrical goods is also located in Bhopal. Therefore there is a big risk of environmental pollution which is very hazardous to our health. Due to this almost every major city and Industrial Township of the state – Indore, Bhopal, Ujjain, Dewas, Nagda, Peethampur, Mandideep and Ratlam is sitting a top a highly toxic sludge underground.

In Mandideep many industries are discharging effluents through drains that join Betwa River. Thus in Bhopal Industrial activities are major sources of air, water and land pollution, leading to illness and loss of life. Pollution is a slow, continuous process. Some illnesses take 20 years to manifest

At many hazardous waste sites in industrial area in Bhopal requiring cleanup, the contaminated soil, groundwater, and/or wastewater contain a mixture of contaminant types. These may include salts, organics, heavy metals, trace elements, and radioactive compounds.

Heavy metals are also included in the main category of environmental pollutants as they can remain in the environment for long periods; their accumulation is potentially hazardous to humans, animals and plants. (Benavides et al., 2005; Gratão et al., 2005)
Heavy metals are serious pollutants in natural environments due to their toxicity, persistence and bioaccumulation problems. The accumulation of heavy metal contaminants in the environment has become a concern due to the health risks to humans and animals. The problem is not restricted to soils with high metal levels, such as mining areas, but also includes those with moderate to low contamination of metals. These toxic elements, such as Cd, Cu and Zn, are present at elevated levels mainly through human activities, as smelting, refining of nonferrous metals, electroplating, agricultural practices (Ross, 1994). Toxic heavy metals cause DNA damage, and they have carcinogenic effects in animals and humans.

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Exposure to high levels of these metals has been linked to adverse effects on human health and wildlife. Lead poisoning in children causes neurological damage leading to reduced intelligence, loss of short term memory, learning disabilities and coordination problems. Cadmium accumulates in the kidneys and is implicated in a range of kidney diseases. Mercury damages to the nervous system, with symptoms as uncontrollable shaking, partial blindness, and deformities in children.

But fact is that industries are required for the economy modernization and development of the city like Bhopal. Therefore environmental pollution with toxic chemicals, metals and xenobiotics is a global problem. There are some preventive or controlling measures for it but most of the conventional remedial technologies are expensive and inhibit the soil fertility; this subsequently causes negative impacts on the ecosystem. To fight against such a big problem there must be an effective solution. The solution to this problem comes from the concept of phytoremediation. Phytoremediation is a cost effective, environmental friendly, aesthetically pleasing approach most suitable for developing countries & city like Bhopal. Phytoremediation is the engineered use of green plants to remove, contain, or render harmless environmental contaminants such as heavy metals, trace elements, organic compounds, and radioactive compounds in soil or water.

Contaminated soils and waters pose a major environmental and human health problem, which may be partially solved by the emerging phytoremediation technology. This cost-effective plant-based approach to remediation takes advantage of the remarkable ability of plants to concentrate elements and compounds from the environment and to metabolize various molecules in their tissues. Toxic heavy metals and organic pollutants are the major targets for phytoremediation. In recent years, knowledge of the physiological and molecular mechanisms of phytoremediation began to emerge together with biological and engineering strategies designed to optimize and improve phytoremediation.
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It is considered an innovative, economical, and environmentally compatible solution for remediating some of heavy metal contaminated sites (Cummingham et al, 1997).

Phytoremediation consists of a collection of four different plant-based technologies, mentioned in table 1, each having a different mechanism of action for the remediation of metal-polluted soil, sediment, or water. These include: ***rhizofiltration***, which involves the use of plants to clean various aquatic environments; ***phytostabilization***, where plants are used to stabilize rather than clean contaminated soil; ***phytovolatilization***, which involves the use of plants to extract certain metals from soil and then release them into the atmosphere through volatilization; and ***phytoextraction***, where plants absorb metals from soil and trans-locate them to the harvestable shoots where they accumulate. Although plants show some ability to reduce the hazards of organic pollutants, the greatest progress in phytoremediation has been made with metals.

No	Process	Mechanism	Contaminant
1.	Rhizofiltration	Rhizosphere accumulation	Organic/Inorganic
2.	Phytostabilisation	Complexation	Inorganics
3.	Phytoextraction	Hyper-accumulation	Inorganics
4.	Phytovolatilization	Volatilisation by leaves	Organics/Inorganics

Table1: *Phytoremediation includes the following processes and mechanisms of contaminant removal*

Streit and Strumm classified the exchange of chemicals between soil and plants. They divided the most common methods of assessing metal toxicity to plants from soil into three categories in the conditions closed system:

(i) Monitoring of the presence or absence of specific plant ecotypes and/or plant species (indicator plant),

(ii) Measurements of metal concentration in tissues of selected species (accumulative bioindicators),

(iii) Recording of physiological and biochemical responses (biomarkers) in sensitive bioindicators.

According to Morikawa and Erkin (2003), the advantages of phytoremediation are - It is an aesthetically pleasing, solar-energy driven cleanup technology;

1. There is minimal environmental disruption and in situ treatment preserves topsoil;
2. It is most useful at sites with shallow, low levels of contamination;
3. It is useful for treating a broad range of environmental contaminants; and
4. It is inexpensive (60-80% or even less costly) than conventional physico-chemical methods (Schnoor, 1997).

II. METHODOLOGY

Qualitative characterization of contaminated sites and sampling of plant and soil material for heavy metal detection -

In the laboratory, the plant samples were placed under running tap water to wash off soil particles from the leaves, stems and roots. Stainless steel knife was used to cut the plant samples into different parts. The plant parts were dried in an oven maintained at 800C, and then pulverized to fine powder using a laboratory stainless grinder. Ground plant samples collected in labeled polythene bags were placed in a desiccators. From each plant sample, 2g was accurately weighed into clean platinum crucibles, ashed at 4500C and then cooled to room temperature in a desiccator. The ash was completely dissolved in 5ml of 20% HCI and the solution was made up to volume in a 100ml volumetric flask. Analysis of the digest for the heavy metal content was carried out using the atomic absorption spectrophotometer. The soil samples were air – dried, crushed and passed through a 2mm sieve. One gram of the soil sample was digested in a 1:1 mixture of concentrated nitric acid and Perchloric acid by heating the mixture plus sample on a water bath in a fume cupboard. The solution was heated to dryness while

the residue was re-dissolved in 5ml of 2M HCI and then

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analyzed for heavy metal detection.

A. Literature review & technology assessment

- To assess the success of current projects
- To estimate the applicability of the project to soil & climatic conditions found in study area
- To identify suitable candidate plants for a particular heavy metal accumulation

B. Plant screening

- Short-season, semi-arid, salt-tolerant species must be selected
- Native and introduced (crop) species are identified
- Check their ability to reduce heavy metal levels

C. Site assessment

- Soil and plant survey and analysis is carried out as mentioned earlier

D. Growth chamber studies

- Optimize plant growth variables for favorable growth
- Elucidate degradation mechanisms of heavy metals and pollutants
- Develop field assessment protocols

E. Field (demonstration) trials

- Establish long-term research plots
- Assess effectiveness of phytoremediation to reduce heavy metal levels

F. Identification of novel genes and the subsequent development of transgenic plants with superior remediation capacities;

G. Better understanding of the ecological interactions involved (e.g. plant-microbe interactions);

H. Appreciation of the effect of the remediation process on ecological interactions; and knowledge of the entry and movement of the pollutant in the ecosystem.

The time it takes to clean up a site using phytoremediation depends on several factors:

- Type and number of plants being used
- Type and amounts of harmful chemicals present
- Size and depth of the polluted area
- Type of soil and conditions present

These factors vary from site to site. Plants may have to be replaced if they are destroyed by bad weather or animals. This adds time to the cleanup. Often it takes many years to clean up a site with phytoremediation.

The following research studies on plant-based cleanup systems must be required:

- Field demonstration of heavy metal removal by selected tree species, including root harvesting,
- Conduct high resolution microanalyses of hyper-accumulator species
- Evaluate procedures for the disposal, processing, and volume reduction of metal-contaminated plant biomass.
- Conduct studies of root and other plant biomass decomposition in soils to understand kinetics and cycling of contaminants.

The cleaning of contaminated soils from heavy metals is the most difficult task, particularly on a large scale. The soil is composed of organic and inorganic solid constituents, water and mixture of different gases present in various proportions. The mineral components vary according to parent materials on which the soil had been developed under a particular set of climatic conditions. Therefore, soils vary enormously in physical, chemical and biological properties. Soil water movement is controlled by physical properties, such as soil structure and texture. The soil moisture has great bearing in controlling solute movement, salt solubility, chemical reactions and microbiological activities and ultimately the bioavailability of the metal ions. A successful phytoremediation program, therefore, must take into consideration variations in soil properties of the specific site.

There are genetic variations among plant species and even among the cultivar of the same species. The mechanisms of metal uptake, accumulation, exclusion, translocation, osmoregulation and compartmentalization vary with each plant species and determine its specific role in phytoremediation. Variations exist for hyper-accumulation of different metals among various plant species and within populations. These variations do not correlate with either the metal concentration in the soil or the degree of metal tolerance in the plant (Pollard et al., 2002). In order to develop new crop species/plants having capabilities of metal extraction from the polluted environment, traditional breeding techniques, hybrid generation through protoplast fusions, and production of mutagens through radiation and chemicals are all in progress. With the development of biotechnology, the capabilities of hyper-accumulators may be greatly enhanced through specific metal gene identification and its transfer in certain promising species. This can play a significant role in the extraction of heavy metals from the polluted soils.

III. Result and Conclusion

Phytoremediation is the most powerful tool against the industrial pollution because it takes advantage of natural plant processes. It requires less equipment and labor than other methods since plants do most of the work.

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Trees and plants can make a site more attractive as well. The site can be cleaned up without removing polluted soil or pumping polluted groundwater. This allows workers to avoid contact with harmful chemicals. Phytoremediation has been successfully tested in many locations, and is being used at several sites.

Phytoremediation is an interdisciplinary technology that can benefit from many different approaches. Results already obtained have indicated that some plants can be effective in toxic metal remediation. The processes that affect metal availability, metal uptake, translocation, chelation, degradation, and volatilization need to be investigated in detail.

The ideal plant for phytoremediation should present rapid growth, high biomass production, and deep roots, be easy to harvest, tolerate various metals and accumulate them in the shoots and/or the plant parts to be analyzed. Some ideal plants for phytoremediation are mentioned in table 2.

Table 2 *- List of some important plants used for vegetation enhanced bioremediation plan*

Plant Species	Common Name	Comments
Amorpha fruticosa	(Indigo bush)	Accumulates lead
Azolla pinnata	(Water velvet)	Biosorbs metals
Bacopa monnieri	(Water hyssop)	Accumulates metals
Hydrilla verticillata	(Hydrilla)	Hyperaccumulates metals
Myriophyllum aquaticum	(Parrot feather)	Transforms and degrades a variety of contaminants
Phragmites australis	(Common reed)	Used in reed bed treatment systems (native genotypes do exist that are not considered invasive)

Further development of phytoremediation requires an integrated multidisciplinary research effort that combines plant biology, genetic engineering, soil chemistry, soil microbiology, as well as agricultural and environmental engineering.

Phytoremediation is still in its research and development phase, with many technical issues needing to be addressed. The results, though encouraging, suggest that further development is needed.

The government agencies in India are not coming forward for application on a large scale unlike United States, Europe, and Australia, although there is much interest in universities and research institutes in India.

Experience with phytoremediation in India reminds us that degraded soils and marginal lands occupy a significant proportion of land in the world. Rehabilitation and management of degraded lands with appropriate agro forestry systems is a promising global opportunity to manage the buildup of greenhouse gases in the atmosphere, which has been little exploited for sequestering carbon through agro forestry on degraded soils.

IV. Future Research Needs

- Government and industry commitment to a multi-year field program. Develop research strategies to address concerns with mixed contaminant systems – (petroleum hydrocarbons - salts - heavy metals)

- Support for establishment of multiple-use, controlled, field-scale phytoremediation research facility.

REFERENCES:

1. *Phytoremediation: Transformation and Control of Contaminants* (Environmental Science & Technology: A Wiley Interscience Series of Texts and Monographs); McCutcheon, S.C., Schnoor, J.L., Eds.; John Wiley & Sons, Inc.:
2. United States Protection Agency Reports (2000): Introduction to Phytoremediation. – EPA 600/R-99/107.
3. Chaudhry, T.M., Hayes, W.J., Khan, A.G. and Khoo, C.S. (1998): Phytoremediation - focusing on accumulator plants that remediate metalcontaminated soils. – Austraaslian Journal of Ecotoxicology. 4; 37-51.
4. Mueller, B., Rock, S., Gowswami, Dib, Ensley, D. (1999): Phytoremediation Decision Tree. – Prepared by - Interstate Technology and Regulatory Cooperation Work Group
5. Anon. 1997. Phytoremediation Becoming Quite "Poplar". The Hazardous Waste Consultant 15(3):1.16-1.20 (May-June 1997).
6. Raskin, I. and Ensley, B. D. (2000): Phytoremediation of Toxic Metals: Using Plants to Clean Up the Environment. – John Wiley & Sons, Inc., New York.
7. Dushenkov, S., Vasudev, D., Kapolnik, Y., Gleba, D., Fleisher, D., Ting K. C. and Ensley, B. (1997): Environmental Science and Technology. 31(12); 3468- 76.
8. Gerhardt, K.E.; Huang, X.-D.; Glick, B.R.; Greenberg, B.M. Phytoremediation and rhizoremediation of organic soil contaminants; Potential and challenges. Plant Sci.
9. Pilon-Smits, E.A.H. Phytoremediation. Annu. Rev. Plant Biol. 2005, 56, 15-39.
10. Abia, A. A., Horsfall, M., & Didi, O. (2003). The use of chemically modified and unmodified cassava waste for the removal of Cd, Cu and Zn ions from aqueous solution. Bioresource Technology, 90, 345–348.
11. Adriano, D. C., Wenzel, W. W., Vangronsveld, J., & Bolan, N. S. (2004). Role of assisted natural remediation in environmental cleanup. Geoderma, 122, 121–142.
12. Albasel, N., & Cottenie, A. (1985). Heavy metal contamination near major highways, industrial and urban areas in Belgium grassland. Water, Air and Soil Pollution, 24, 103–109.
13. Al-Chalabi, A. S., & Hawker, D. (2000). Distribution of vehicular lead in roadside soils of major roads of Brisbane,
14. Prabha K. Padmavathiamma & Loretta Y. Li Phytoremediation Technology: Hyper-accumulation of Metals in Plants Received: 13 October 2006 / Accepted: 1 April 2007 / Published online: 22 May 2007
15. WHO (1997). Health and environment in sustainable development. Geneva: WHO
16. Morikawa, H., Erkin, O.C.(2003). Basic processes in phytoremediation and some applications to air pollution control. Chemosphere 52(9):1553–1558.
17. Champion: Stuart Lunn, Ph.D. Imperial Oil Resources R&D Providers: R.E. Farrell, Ph.D. & J.J. Germida, Ph.D. Assessment of Phytoremediation as an In-Situ Technique for Cleaning Oil Contaminated Sites
18. Cummingham, S. D. Kruger, E. L. Anderson, T. and Coasts, J. R. 1997). Phytoremediation of Contaminated Soil and Water. ACS Symposium Series 604. American Society, Washington, DC.23pp.
19. Ross SM (1994). Toxic Metal in Soil–Plant Systems. Wiley, Chichester.
20. Benavides, M.P., Gallego, S.M and Tomaro, M.L, 2005. Cadmium toxicity in plants.Braz. J Plant Physiol., 17: 21-34.
21. Hrishikesh Upadhyaya1, Sanjib Kumar Panda2, Mrinal Kanti Bhattacharjee1 and Sakhi Dutta1 “Role of arbuscular mycorrhiza in heavy metal tolerance in plants: prospects for phytoremediation”.
22. Streit B., Strumm W., Chemical properties of metals and the process of bioaccumulation in terrestrial plants, in Plants as Biomonitors, in: Indicators for Heavy Metals in the Terrestial Environment, VCH, Weinheim, 381, 1993.
23. Pollard AJ, Powell KD, Harper FA, Smith JAC. The genetic basis of metal hyperaccumulation in plants. *Crit Rev Plant Sci.* 2002; 21(6): 539–566. doi: 10.1080/0735-260291044359.

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