Phytoremediation: sustainable approach for the removal of Heavy metals from the environment using plants

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Abstract:

These studies Review the plant species for phytoremediation potential and capability to consumption and accrue Heavy metals concentration. Natural renewable resources are valuable assets for human development. Extreme utilization of the resources and severely contaminated due to the influence of human activity on nature. Resources Contamination with toxic metals is a wide-ranging environmental issue resultant from various sources like Inorganic fertilizer, pesticides, leaching, and dumping of pollutants. The Remediation of sites polluted with toxic metals is predominantly difficult. Conventional techniques for recovery are expensive and environmentally uncongenial. Plant-based technology known as Phytoremediation has been proposed as an economical environment-friendly alternative technology to the conventional remediation approaches.

1. Introduction:

Addressing environmental pollution of soil, water is one of the substantial challenges of nowadays. Heavy metal contamination in soil and water bodies had a significant effect on the ecosystem and has its harmful collision on human health and agriculture [1]. An immoderate amount of heavy metal accumulation is an alarming environmental fact and decreased in yield due to loss of soil microbial activity and soil fertility. Therefore, cleansing of heavy metal contamination is very imperative to minimize the risks and for the safeguarding of environmental and ecological renovation. The different method has been used for the remediation process [2]. Conventional techniques for retrieval are an overpriced and environmentally unfavorable system. So, remediation of heavy metals accumulation could be the only effectual choice to shrink the unconstructive effects on the environmental ecosystem [3]. As a result, observance insight of the above particulars and effort has been made in this article to review the current status of Phytoremediation for remediating heavy metals from contaminated zones [4, 5]. Phytoremediation is proposed a promising substitute, appropriate and ecological climate-friendly than traditional conventional techniques. Phytoremediation makes use of different plant species for accumulation or the Contamination process. Enhanced information about phytoremediation soon-to-be is necessary to boost the use of this technique soon for remediation of the contaminated sector in a profitable and sustainable approach. The reviews analyzed the application of plants for the remediation process and its outspread appropriateness.

2. Heavy metal pollution in Environment:
Heavy-metal contamination is considered a principal cause of ecological contagion. Heavy-metal effluence in groundwater and soil give consequential hazard to the environment and natural resources. Heavy metal pollution has become a serious threat worldwide. According to the Comprehensive Environmental Pollution Index (CEPI) rating, there are 43 critically polluted zones in more than 16 major states in India with a rating of more than 70 on a scale of 1 to 100. The possible sources of heavy metal contamination can be rapid urbanization, industrialization, agricultural and mining activities, etc. These heavy metals are toxic and their accumulation in the ecosystem poses serious risks to the various aspects of the natural environment. When they get accumulated in water bodies, they stimulate the production of reactive oxygen species and can severely damage the aquatic flora and fauna. They can affect the soil micro-flora and affect the soil enzymatic activities by proxy as well. They also pose several health risks to the human body. They can damage and severely alter the functioning of organs and chronic exposure to these metals can also lead to cancer. For example, chromium exposure has been related to lung damage and lung cancer, aluminum has been associated with Alzheimer’s and Parkinson’s disease, cadmium exposure can lead to severe kidney damage and hypertension, etc.

Generally, humans are more likely to be exposed to such heavy metals through the consumption of heavy metal contaminated water. Nearly 1.6 million kids across the world die each year due to drinking water contaminated with heavy metals. More than 42 major rivers cross India have at least two toxic metals beyond their permissible limits according to the Central Water Commission. Soil pollution by heavy metals has also become a grave issue worldwide. In India alone, heavy metals like Copper, Cadmium, Chromium, etc. have high Cp value (Potential contamination Index) of 3 or more, which indicates very high contamination by such metals. Thus, the cleanup of such metals is of utmost importance. However, the conventional methods of remediation, such as, in situ vitrification, soil incineration, excavation, and landfill, etc. have major disadvantages of their high cost of execution, the requirement of intensive labor, the irreversible impact it poses on the soil properties, and soil micro-flora and many more. Hence, there is a grave necessity to devise a substitutive approach to protect the environment and keep it pollution-free. This is where the role of phytoremediation comes into the picture, wherein certain plants are used as an alternate medium to remediate polluted water and/or soil.

### Table 1. Types of Pollutants

| Pollutants Types               |
|-------------------------------|
| **Organic pollutants**        |
| Organic compounds             |
| (Poly aromatic hydrocarbons, chlorinated solvents) |
| **Inorganic pollutants**      |
| Chemical fertilizer, Pesticides Heavy Metals like Arsenic, Zinc cadmium, Chromium, Lead, Mercury, etc |

Physicochemical methods are used to eradicate the contaminants which are highly expensive and tedious. Plant remediation treatment is one of the best economical profitable rising technologies with existing applications.

### 3. Technologies for the Remediation

Different procedures are in progress for remediating the contaminants.

#### 3.1 Physicochemical Remediation Processes
Physicochemical treatments are separation; filtration, adsorption, sedimentation, coagulation; Chemicals, and Oxidation were widely used to remediation. Most of the methods accessible have an impact on Human health and the environments.

### 3.2 Plant Remediation Processes

Biological methods using plants are carried out for remediation methods are a very easy and cheap technique than the physicochemical system.

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### 4. Phytoremediation

Phytoremediation is the use of green plants to reduce the toxic contaminants from the environment. Compared to the chemical and conventional processes natural processes should be preferred more when it comes to remediation. Coming to the method in which phytoremediation works, it depends on the observed co-metabolism between the plant roots and microorganisms present in the rhizosphere. Plant’s roots provide organic sources to the microorganisms and these microorganisms in turn degrade the contaminants.

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![Schematic representation of phytoremediation approach](https://via.placeholder.com/150)

**Figure 1.** Schematic representation of phytoremediation approach
Phytoremediation is one of the best alternatives for the removal of contaminants. It is more preferable and alluring as a remediation method due to its low cost, eco-friendliness, and most importantly due to the potential utilization of by-products that can be accomplished.

Table 2. Various approaches on phytoremediation

| Methods                              | Explanation                                                                 |
|--------------------------------------|------------------------------------------------------------------------------|
| Phytoextraction                      | Absorption of contaminants by roots.                                        |
| Phytofiltration                      | Uses of plants to absorb, concentrate or precipitate contaminants from an aqueous medium through their roots |
| Phytodegradation (Phyto transformation) | Organic contaminants are degraded (metabolized) or mineralized inside plant cells by specific enzymes |
| Phyto extraction (Phytoconcentration) | Contaminants are concentrated in the roots, stem of the plants               |
| Phyto degradation                    | The Process where plant enzymes help for catalyzing to the breakdown of the contaminants |
| Phytostabilization (Phytoimmobilization) | Avoid mobilization of contaminants                                          |
| Phytovolatilization                  | Plants to absorb and volatilize certain metals                               |
| Rhizodegradation                     | Degrading contaminants in the rhizosphere by rhizosphere growing microorganisms. |

5. Plant species for Phytoremediation

Several plant species are acknowledged and experienced based on their qualities for the accretion of incompatible contaminants or pollutants. By using these green technology pollutants are removed from the contaminated sites. The plant has universal recognition for the removal of pollutants from the contaminated sites in an eco-friendly mode.

Characteristics for Phytoremediation plants should have some factors like pH, solar radiation, also maintained in proper conditions. The main factor for remediation is root depth and climatic conditions. Long feathery, fast growth rate, high biomass, and cost-effectiveness it is an outstanding remediated plant than other aquatic plants due to its incline nature.

Among the plant species, water lettuce (Pistia stratiotes) aquatic plants are the most significant characteristic of successful remediation process [16]. The selection of suitable plants for phytoremediation depends on many factors like deep root structure, ability to adapt to the local climate, soil compatibility, growth rate, etc. Plants like Indian mustard, sunflower, etc for soil phytoremediation, and in the case of water phytoremediation, plants like water hyacinth and pistia are generally utilized. Pistia stratiotes L (water lettuce) have advantages over other phytoremediation plants because of their long feathery leaves, fast growth rate, and high biomass. The seed germination period of these water lettuces is around 6-7 days and it takes around 65-85 days for its maturation.
Figure 2. Water Lettuce

The Plant remediation method does not require special apparatus like conventional methods. The main set of apparatus required includes a spectrophotometer, colorimeter, pH meter, etc. In this experiment, SEM microanalysis is employed to detect and locate the exact location of heavy metal present or taken up by the plant tissue. It can provide information on speciation and localization of metals in the plants. Phytoremediation is used in different media, for example, air, soils, groundwater, wastewater stream (industrial agricultural, municipal, sewage). Coming to the many advantages of this experiment, it is aesthetically pleasing, it is less expensive as compared to other conventional methods, it can be easily monitored, and it also reduces soil erosion as well as transport of contaminants by wind and by using a single plant multiple contaminants can be removed. From different studies, it is proved water lettuce is an excellent accumulator of Lead, Zinc Copper, Cadmium, and Magnesium, etc.

6. Process of Phytoremediation
Plants can remove contaminants from the ground water and soil and store, metabolize or volatilize them. Plant root takes contaminants from the ground into the body of the plant and action occurs. In Rhizosphere (Plant root zone). Plant roots also support a wide variety of microorganisms in the subsurface. This is due to chemicals exuded by plant roots which provide carbon and energy for microbial growth. The combination of plants and microorganisms emerges to increase the biodegradation of pollutants. The roots also provide organic carbon sources to promote co-metabolism in the rhizosphere.

6.1 Harvesting Of Plant Material
Once plants have accumulated waste materials, plant shoots are harvested to recover the metal. If organic contaminants are degraded to harmless compounds, the disposal may not be required.

7. How long phytoremediation does take?
Time depends on Type and Number of plants used; Amount and type of contaminants present; Types of soil and conditions present

7.1 Technology Limitations
Possible disadvantages associated with all phytoremediation/plant-assisted remediation techniques include:

- Slow growth and low biomass require long-term commitment.
- Not possible to completely prevent the leaching of contaminants into the groundwater
- Requires the safe disposal of the affected plant material

7.2 Field study

| Heavy metal | Plant species       | References   |
|------------|---------------------|--------------|
| Cu         | Pteris vittata      | Wangetal (2012) |
| Pb         | Medicago sativa    | Koptsik (2014) |
| Cd         | Oryza sativa       | Mekawy (2018)  |

8. Conclusions
The review of the study, conclude the benefits of aquatic plants for the removal of Contaminants are vast because it is considered to be an innovative and cost-effective, alternative eco-friendly to conventional cleanup methods for the sustainability of entire ecosystems. Heavy metals in our environment as an unrelenting contaminant require absolute removal for a completely remedial point. Phytoremediation is a device for environmental pollution management. The selection of plant species is the key point in remediation methods. To conclude, ornamentals plants can also be used for phytoremediation of heavy metals. It has an advantage over conventional methods because it is less expensive and several factors need to be kept in mind before experimenting, for example, humidity, wind, temperature, and amount of contaminants, and so on. Phytoremediation is one of the best alternatives. However, every experiment has its limitations; to minimize the limitation, prolonged research needs to be done. For commercialization, the plants need to be tested in the field for phytoremediation efficiency. Identification of desirable traits in natural hyper accumulator’s selection and breeding techniques should be done and these different desirable traits can be combined into a single plant species. Developments in Phytoremediation applications are giving new windows of opportunity to develop more cost-effective and environmentally acceptable treatment technology. This review suggests that use of aquatic plant species may be used for wasteland reclamations.

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