Phytoremediation: A New Green-Technology Approach in Site Clean-up of Heavy Metals

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ABSTRACT: ***Water and soil pollutant with Heavy Metals (HMs) is a major concern all over the world. It badly affects the human health and plant growth as well. The contaminated water and soil are remediating by the process of phytoremediation that gives prospect for recovering pristine stage of the water and soil's environment. The phytoremediation technology which is cost-effective that is used for heavy metals removal and other contaminant from water and soil. The plants who have hyperaccumulator, they use its inner multipart system of largely efficient mechanism that controlling uptake, trafficking, accumulated & detoxifying of the heavy metal. Numerous approached for phytoremediation shows that instead of limitations, phytoremediation is most efficient approach for the heavy metals' removal and contaminants from water and soil. Phytoremediation is cost effective and have few side effects as compared to chemical and physical approaches. The latest advancements in biotechnology plays a challenging part in the growth of novel hyperaccumulator from transfer of metallic gene by low to high species of biomass that produce cultivated species in future. Latest progress in practical & research application for phytoremediation to water & soil is there. In the future, phytoremediation's efficacy of various plants for specific heavy metals have tested in farm condition to understand the feasibility for the technology of phytoremediation for the purpose of commercialization. Different required traits might be combined in single species of plant.***

KEYWORDS: ***Accumulation, Heavy Metals, Phytoremediation, Plants, Soil, Technology, Uptake, Water.***

INTRODUCTION

Phytoremediation has a great success in green-technology. It is mainly depending upon various factors. The first one is plants, while accumulated high-concentrated metal plants should produce enough biomass. Concentration of the metals gets lowered by increasing in biomass that allow large amount of overall accumulated metals. Second is the plants which are accumulating materials should be very responsive to farming practices which allows continuous planting & harvesting of tissues that are rich in metals. These all are managed on small-scale but not practicable on large-scale. The whole plant needs to get removed if metals get anyhow accumulated in its roots. Heavy metals found naturally in water and soil and released from different natural and manmade resources. Heavy metals disturb the water uptake and nutrient uptake also that affects the production to Reactive Oxygenized Species (ROS) that decreases efficacy to photosynthesis, change cell's division & nitrogen metabolism which greatly affects plants growth. Continuously heavy metal uptakes into human by the contaminated food which causes oxygenized stress from large productions of Reactive Oxygen Species, many immunology related syndrome that includes effects of cancer, mutagenesis and teratogenesis and cancer of upper gastrointestine. Three remediate methods are used for cleaning-up of contamination of heavy metals in soil which is contaminated and that are: Physical, Chemical and Biological. The physical approach comprises interment and pit of soil at harmful waste-site, fixation, leaching by acids for desorbing & leaching metal by soil through clean soil's residues return, precipitation which is followed by the sedimentation, reverse osmosis, micro filteration and ion exchange. These approaches have high cost and much side-effects. The biological approach involves: the microorganism uses for detoxifying metals by transformation of valency, chemical precipitation and volatization, plants of special types are used to decontaminate water and soil by non activation of metals by translocation of them into ariel part. The approach is known as Phytoremediation that is novel & greatly favorable technologies to renovation for contaminated site & is cost-effective as compared to physical and chemical approach.

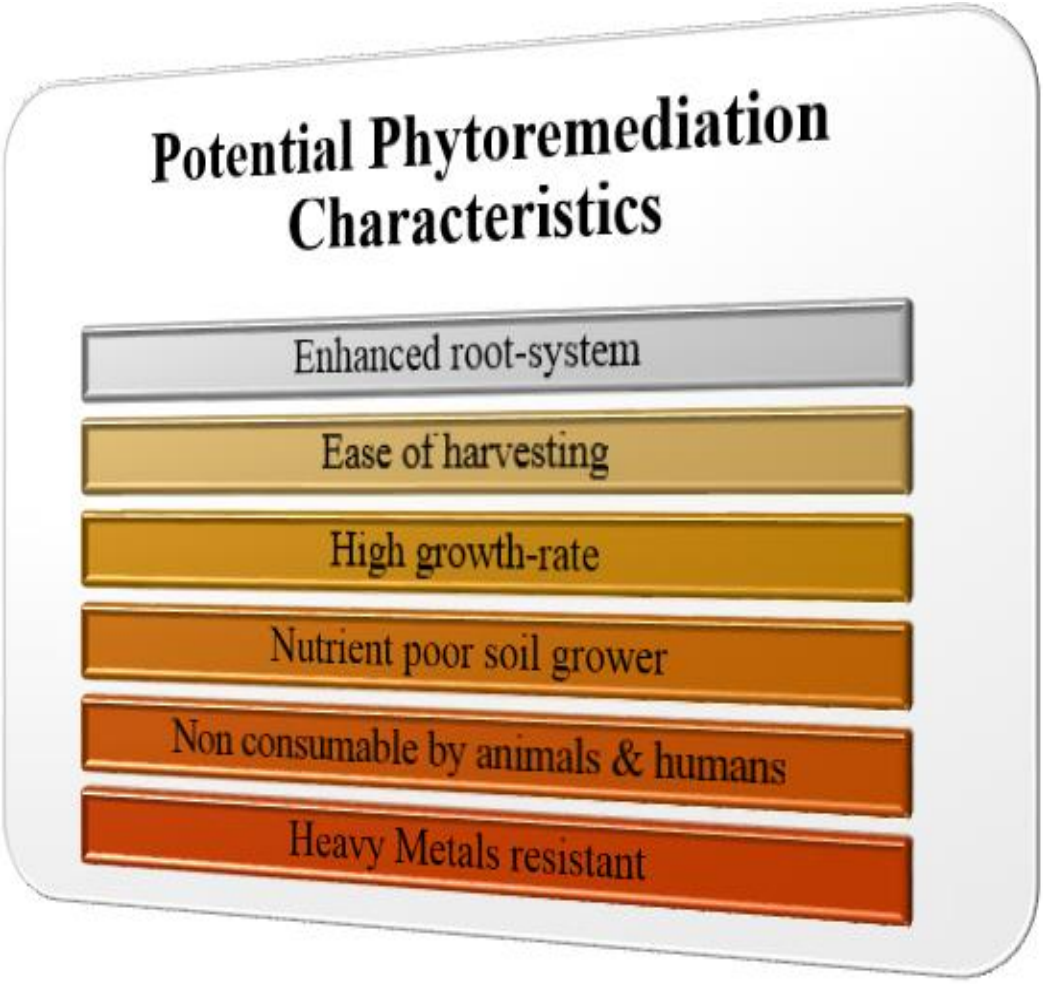

Figure 1: Illustrating the Potential Characteristics of Phytoremediation in Cleaning-Up of Heavy-Metals

Bioremediation or phytoremediation is a type of processes into which biological organism used for removing pollution that re-established natural condition. Commonly, plants & microorganisms gets used for detoxifying heavy-metal by the soil. Many bioremediation's technique like: bioreaction, rhizofilteration, biostimulation, bioaugmentation, bioleaching & bioinventing are used and are helpful in removing toxicity of heavy-metals. It is among cost effective and ecofriendly options in rectifying soil's-contaminant. Phytoremediation comprises plants and microorganisms both that detoxifying heavy metals present in water and soil. It is an alternative method which is non-invasively, ecofriendly & cost-effectively green-technologies that tackle and cleaning-up of sites having median-level or low-level heavy metals. There are various potential characteristics (Figure 1) of phytoremediation in heavy metals like- enhancing of root-system, easy-harvesting, growth rate increased, poor growth soil nutrient, is non-consumable by humans & animals and is resistant to heavy metals. The trees have widespread roots, easy propagation, rate of transpiration is high and have high production of biomass. There is outstanding variability of clonal in their accumulation capability to tolerate heavy metals. To maintain good quality non-contaminant water and soil, efforts have been made continuously for the development of technologies which are sustainable, economically reasonable and is easy to use. On a small-scale physiochemical approach are used in order to remedying contaminated water and soil. Plant species are used for cleaning up of polluted water and soil called as phytoremediation that is gaining attention which is increased due to cheaper technology. Many of the plant's species have tested and identified for the traits in the accumulation or uptake of heavy metals.

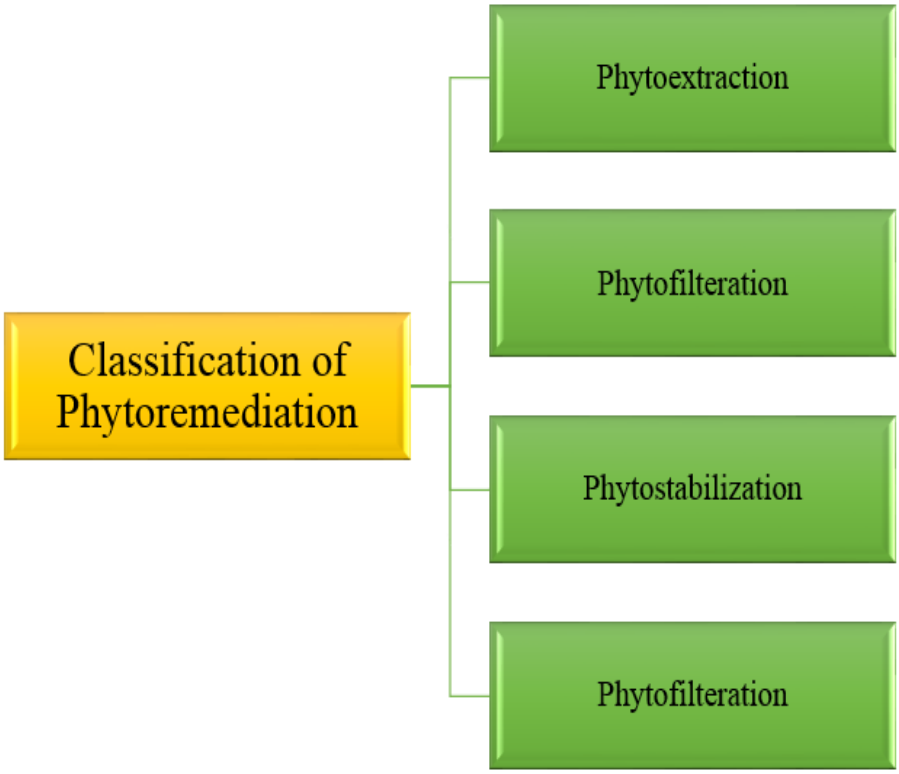

Figure 2: Illustrating various Classifications of Phytoremediation in cleaning-up Heavy metals

Phytoremediation is categorized into four components and they are: Phyto stabilization, Phyto filteration, Phyto extraction and Phyto degradation (Figure 2).

- Phyto extraction- also called as phytoaccumulation which uptake the contamination from water and soil from roots to transfer that contaminants to leaves and shoots. These plants are slow growing and are small and are rarely found species that are restricted size of population & limited its distributions into whole ecological system.
- Phyto filteration- it is the process of removing contaminants from waste water and ground water with the plants. To this, various plant part used like- seedling, plant shoots(excised) & roots. Filtrates of plants can be terrestrial, aquatic or semi-aquatic, effective capability of metal binding and slow growth. The plants which are grown in hydroponic areas are very effective in rhizofilteration so to adsorb contaminants as compared to physical water plant.
- Phyto stabilization- also called phtodeposition/phtosequestration that deals with fixing pollutants in the soil nearby roots and not in tissues which prevent heavy metals migrated either in food web or ground water. It is totally differently to all other approach as not permanent solutions & utilized majorly for restricting movement to heavy metals.
- Phyto stimulation- also known as rhizodegradation in which microorganism used for breaking down organic contaminant in soil. It increases metal mobility & availability in the soil which help the plants for growing betterly underside the metals strain conditions. Plants produce some enzymes also that degrade organic pollutants in the soil.

LITERATURE REVIEW

Cleaning of the contaminated soil by heavy metal is most complex-tasks specially onto the large-scale. Soil made up of inorganic & the organic solids constituent gases & water mixtures which is present into different amount. Metal's hyperaccumulation in different plant species have investigated and progress have made substantially. Khalid et al.[1] studied the contamination of soil and heavy metal all over the globe. They found bioremediation as more economical and ecologically friendly than other chemical and physical methods and assistance of microbes in genetically modified species of plants as a high future perspective. Hedia Hdiji et al. [2] studied the long term impact of cadmium on mineral present in the plant *Solanum lycopersicum* and its consequences on tomato plant. The presence of cadmium decreases the copper and zinc contents present in the shoots and increasing them in roots. Atul Bhargava et al. [3]studied the enhanced approached that increase phtoextraction of the heavy metals and gave their view on accumulation mechanism and metal tolerance in environment and plants and the gene factors as well that affect heavy metal. They

have studied the classical tools of genetic breeding and engineering that create remediation cultivars. David T. Tsao [4]studied the overview of phytotechnology which is described as vegetation use to contain, degrade and remove the organic and inorganic contaminants present in groundwater or soil. They have studied the basic phytotechnological process occur in plant system. Hazrat Ali et al.[5] studied the concept and the applications of phytoremediation and found that plants and microbes present in the soil that reduce the toxic effects of contamination in environment and found that new molecular tools have been used for better understanding of metal uptake mechanism and plant tolerance.

U. Kramer and A. Chardonnes[6] studied usage of the transgenic variety of plant in phytoremediation for contaminated soil by some of the trace element & found that a number of transgenic varieties of have generated to modify the uptake, tolerance of trace elements and the phenotype of such plants provides significant insight for improvement of engineered strategies. Natasha Grotz and Mary Lou Guerinot[7] studied the different molecular aspect of iron, copper and zinc via. Homeostasis in plant. They also have taken the aspects of distribution, uptake and chelation in both humans and plants. They have studied the proper transport of metals and homeostatis are serious for the development and growth of plants. Elizabeth Pilon-Smits[8] studied phytoremediation of plant biology. They have studied the use of microbes and plants foe ecological cleanup that have earned acceptance for engineered based remediation method which is cost effective, complementary and non-invasive and their application on organic and inorganic contamination to increase its efficiency. Ilya Raskin, Robert D Smith et al.[9] studied that phytoremediation use plant to remove contaminants from environment. The metal accumulation plant use which clean water and soil contamination with toxic metal is more rapidly developed component of this cost-effective and ecofriendly technology. Amanullah Mahar et al. [10]studied different opportunities and challenges in heavy metals in contaminated soil. They have studied that heavy metals of contaminated soil are more alarming ecological fact and to clean up the soil is the greatest challenge in almost countries. Also, Phytostabilization and Phytoextraction are the most challenging approach for remediation. There are some limitations to the approach also. The physical and chemical approach of bioremediation is much time consuming and have slow development and growth and is efficient in low level & moderate level of contamination and also these approaches have low bioavailability.

DISCUSSION

Plants shows various mechanisms (Figure 3) to cop-up with heavy metals in excess. The mechanisms identify the amount of accumulated metals by plants. Up-taking of metals in roots is controlled by the ion-flux by plasmalemma proteins for metal transport, binding-effects of the cell-walls & exudation to the ions of organic acids. The chelation and transportation of metals are done by peptidicchlelators, in the cytoplasm. Excess metal ion have directed towards the apoplast from transportation of the membrane. Metal gets mobilizing by xylem by the roots to ariel structure in process which is done by transpiration. A controlled network of chelators and membrane transporters directs metals in the leaf cells to the final destination. The metal stress response includes general defense protein expressions & signaling of elements like: ethylene and calcium.

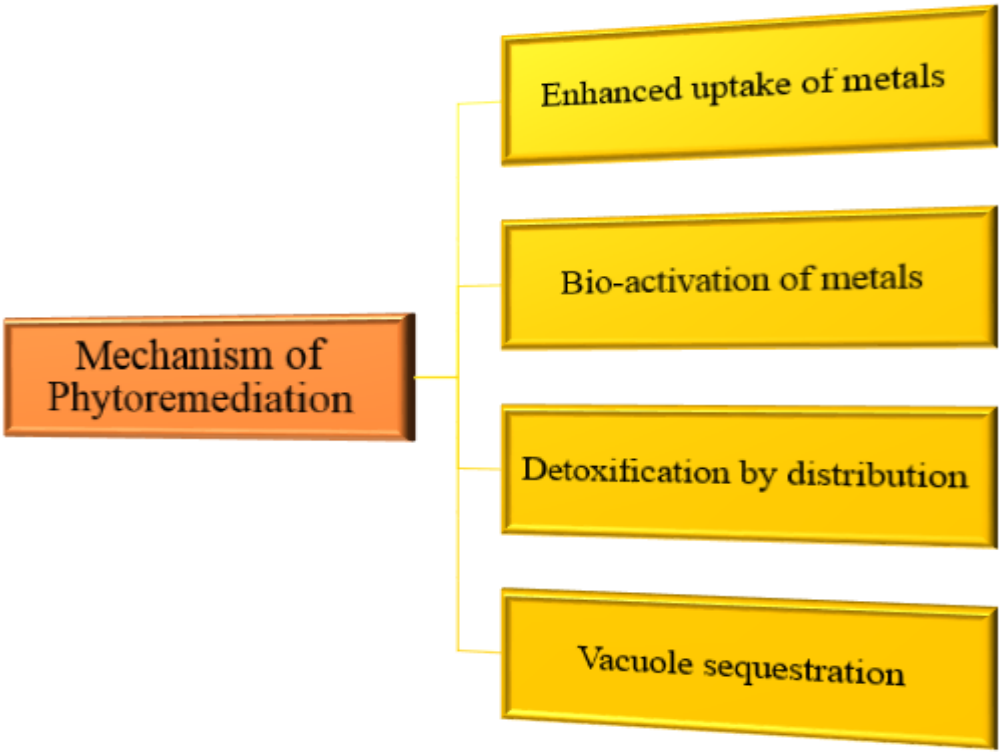

Figure 3: Illustrates the Mechanism of Phytoremediation for Heavy metals

1. *Uptake by roots*:

Uptake by roots is the first stage in heavy metal uptake that involves absorption of ions from soil & distributes in the root cell. These are many compound which performs functions for the accumulation & transportation to heavy metals into the tissue & many another location such as metal ligand. Siderophore like avenic acid and mugineic acid that are releasing by the plant's species which enhances the biological availability to heavy metals by soil's for the root's uptake that is reported into species of grass.

2. *Vacuole sequestration*:

Heavy metals are sequestered in vacuole of the plant cell, after the uptake by root. Heavy metals enter the cytosol by Zinc/Ion regulated transporters that further stimulate the Phytochelatins synthetase enzymes' that catalyzes the synthesis of Phytochelatin by glutathionine. The heavy metal Phytochelatin complex has low molecule weightage complexes that transported into the vacuoles by the tonoplast located ATP-Binding Cassettes transporter. In vacuole with low molecular weight heavy metals complex accumulated in high molecular weight complex having more heavy metals. Heavy metals that enter the vacuole by mechanism of direct exchange of several heavy metals' protons exchange transport like: Natural Resistance Associate Macrophage Proteins & Metal Tolerance Proteins. These transporters are resided in tonoplast that mediate passage for metal ions for remobilization or compartmentation.

3. *Enhancement by metal's uptake*:

Mycorrhiza, the symbiotic associations to the fungi by plants that protect to heavy metals pollution through bind in the component of cell wall/through storage of higher amount to heavy metals into the cytosol. It produces substance that stimulate growth for plants, though encourage mineral nutrition and increase growth & biomass which is necessary to phytoremediation.

4. *Compartmentalization of Metals:*

Cell wall binds to metal ion at the cellular level assist them to cytoplasm from cations exchanging. Metal either binds towards pectin's or to protein such as the oxalate oxidases. Metal may have diffused into apoplast to root cells but the transportation of it gets blocked through casparian strips which is impermeable into endodermal layers. Plant has sequences for metal transporter that are involving into uptake of metals & homeostatis that regulate its movement to the vacuolar tissue and symplast.

Phytoremediation is a cleaning up green technologies that involve in usage for the plant & its related rhizophore microbe to treat environment pollutants like organic compound, heavy metals, soil industrial wastes or groundwater. The common advantages for the phytoremediation: cheap, ecofriendly, energy efficient, noninvasive & the method like burning, soil's washing, metal recycling, soil's excavation. They have also economically secondary usage viability: energy from paper production, pulp and biomass. Some factor affects uptake to heavy metal in the plant & that are: environmental factors, size of metals, plant age, microbial colonization and translocation to different parts. Though phytoremediation, non-invasive, sun-generated technique to the accumulations of removing soil and heavy metals.

There are various applications (Figure 4) of Phytoremediation in heavy-metal cleanup. One of the areas of application of phytoremediation is Ecotoxicology and ecophysiology in which nutrient availability, its efficiency and its deficiency for optimization of crop yield can be detailed studied. Other area is the area of environmental chemistry, waste management and mind reclamation for bioremediation and restoration of metal polluted in the ecosystem. The other application is the area of agriculture and food industry and nutritional sciences for soil and plant plays an important role for supply of nutrients on sustainable basis. phytoremediation has an application in the field of clinical biochemistry in the usage of radioloabelled antibody and its disposal. Use of plant as source of certain nutrient disorder in medicine and pharmacology. The energy of atomic sector in the nuclear weapon testing of mainly production and nuclear power production.

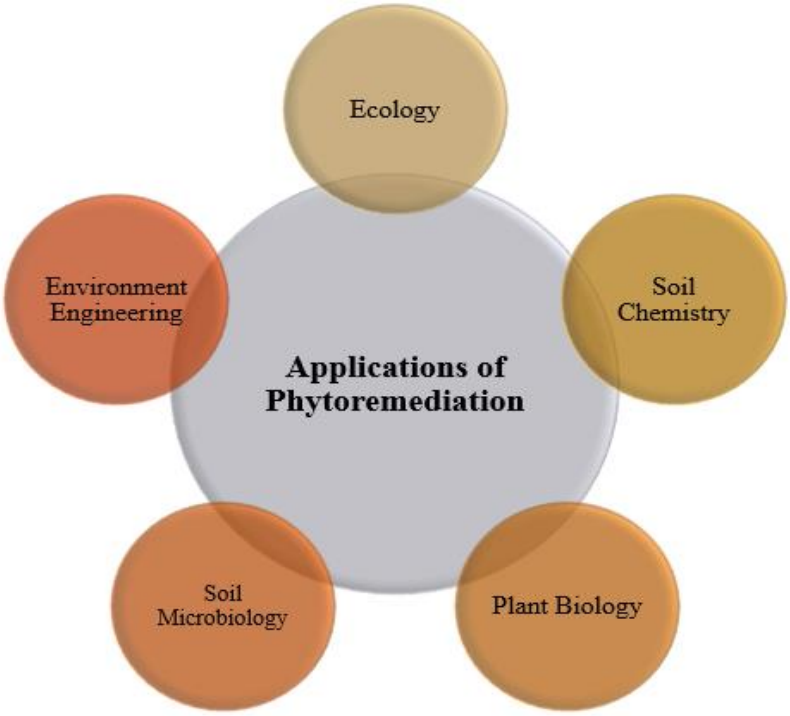

Figure 4: Illustrating various applications of Phytoremediation in Heavy metals

Phytoremediation in Green-Technology has various limitations (Figure 5) also. It consumes much time in cleaning up, the development and growth of hyperaccumulators is much slow, Disease attack and biotic factors may have cooperated capability of hyperaccumulators accumulation, weather conditions and climate conditions that affect hyper accumulator plant's performance, efficient in the moderate & the low level pollution only, harden for mobilizing and limited bioavailability that is more tightly bound of metal ion by soil, food web contamination risk in case mismanagement.

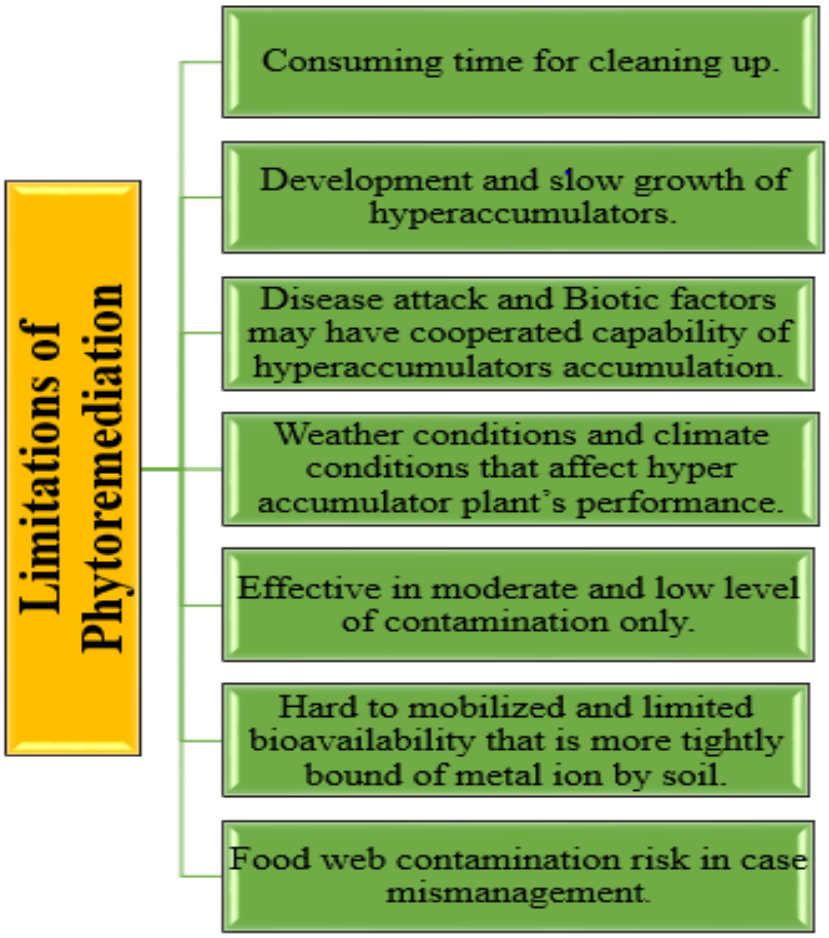

Figure 5: Illustrating the limitations of Phytoremediation in a Green-Technology Approach

CONCLUSION

Water & Soil contamination by heavy metal becomes serious concern, that's why ecological friendly & sun driven technology that has acceptance of community needs to explored. Phytoremediation is among that concern that need to explore further for the contamination removal. It reveals that this cost-effective technology which is called phytoremediation is being used to remedying heavy metals and its pollutants from polluted water and soil. It needs better knowledge of different processes that are involved in removal of hyper accumulators. The contamination in the environment of heavy metals like: plant, air, soil and water, all are the major concerns because of its potential effect on animal and human health. Effective and cheaper technology need for protecting precious natural resource. Plant species have genetic variation among them. The metal uptake mechanism, exclusion, accumulation, osmoregulation, translocation, may differ with every plant species and identify its special role in phytoremediation.

To develop new crop plants that have capability of extraction of metals from contaminated environment, hybrid generation by protoplast fusion, traditional breeding methods, mutagen production by chemicals and radiations, they all are in progress. Biotechnology development enhanced the capability of hyperaccumulators by specific identification of metal genes and its transfer in some significant species. This plays significant role for heavy metals extraction from contaminated soil. The cleaning technology usage is site-specific because of climatic or spatial variation which is not even economical feasible. Latest advancements in the Plant's Biotechnology made novel hope to hyper accumulating species developments. Future Prospective; Phytoremediation uses specific property of hyperaccumulation to the plants which work like pumping machines to the removal of heavy metals by water & soil. phytoremediation's are in the initial stages that needs new strategy to the growth. This is attained by either exploration of hyperaccumulator diversity or by manipulation of genes through genetic engineering.

Involvement of foreign genes in plants for cleaning up of heavy metals pollution by water and soil is feasible. No ideal plant has been established best hyperaccumulator for accumulation and hyper tolerance unless complete genome information has been ensured. The interaction of transgene hyper accumulator plant's

microbe's interactions becomes highly effective for absorbing, translocation & accumulation to heavy metals into plants. Consequently, establishing and suitable microorganism for phytoremediation needs tolerable attentions. Proper agricultural managements practice for utilizing cholate's associated remediation's with the combination to transgenic approaches require for getting explore to accumulate heavy metal. Phytoremediation in reference to the green technology has various limitations also. It is much needed to overcomes those limitations for sustainability approach for the coming future generation. Growth and development of hyperaccumulator is slow. This is the major limitation and needs to look after it for the healthy environment. There is a serious necessity to recognize the role of plant hormone for increasing the potential of hyper accumulator in plants. Using several technologies in combination of plants and soil microbes is being challenging to sustainable remedying and environmental safety. Interdisciplinary research for plants by soil microbiologist, soil chemists, plant biochemist, ecologist, and physiologists will help in answering challenges or limitations faced in the process of phytoremediation. Researchers/scientists need to determine & recommend the various commercial application of phytoremediation for the removal of contaminants from water and soil.

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