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IMPLEMENTATION OF PHYTOREMEDIATION AS AN ECO FRIENDLY APPROACH FOR ENVIRONMENTAL CLEAN-UP

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ABSTRACT :- Environmental contamination due to urbanization, industrialization, anthropogenic activities, heavy metal accumulation, military and agricultural activities etc. is of serious ecotoxicological concern worldwide. Plants are currently used to extract the pollutants and remove them from the environment. This simple cost effective eco-friendly green technology is known as phytoremediation. Phytoremediation is the most promising way that could be successfully used to minimize the concentrations of toxic substances from the environment. Therefore, it is indispensable to focus on the different strategies of phytoremediation in order to enhance its performance. For this, a better understanding of the various phytoremediation processes such as phytoextraction, phytofiltration, phytostabilization, phytodegradation, and phytovolatilization is required. The current review work outlines the general aspects of phytoremediation, along with its advantages and limitations. It also provides a more comprehensive view of the present status of phytoremediation with a much wider range of its applications to environmental pollution control. Furthermore, the recent developments of science and technology related to phytoremediation research are also discussed here to improve and focus on future trends and prospects of global relevance.

KEYWORDS:- Phytoremediation, environmental contamination, phytoextraction, phytofiltration, phytodegradation, phytovolatilization.

INTRODUCTION:-

Around the world, there is an increasing trend in areas of land and waters that are affected by environmental contamination either due to ignorance, lack of vision, or carelessness. The major cause of environmental pollution is either naturally or due to various anthropogenic activities (Farraji et al., 2020). There has been an increasing amount of heavy metals introduction in the environment mainly due to industrialization and urbanization, which needs significant attention all over the world (Suman et al., 2018; Ashraf et al., 2019; Yan et al., 2020).

In addition, it is also necessary for improving the environmental conditions because of overpopulation that is one of the main causes of industrialization (Farraji *et al.*, 2016). Generally, for the purpose of decontamination of polluted sites, various physicochemical technologies are employed like chemical precipitation, membrane filtration, adsorption, coagulation-flocculation, photocatalytic degradation, ion exchange, oxidation with ozone and hydrogen peroxide (Fu and Wang, 2011) which are highly expensive and difficult to be used as one complete process in order to successfully accomplish environmental standards (Ahmaruzzaman, 2011; Hasan *et al.*, 2019). Thus, a cost effective eco-friendly green technology is urgently required for improving the degraded environmental conditions. Phytoremediation is one such environmentally sound technology for pollution prevention, control and remediation. It is the direct use of plants to improve degraded environments (Farraji *et al.*, 2020). Phytoremediation has now been widely applied to water, air, and soil pollution remediation (Mayo *et al.*, 2017; Liu *et al.*, 2020). There are a specific number of mechanisms involved in phytoremediation (Awa and Hadibarata, 2020; Farraji *et al.*, 2020) which are mainly targeted to achieve the actual goal of phytoremediation. Nowadays, numerous of advanced techniques are being added as new subsets for this green technology and additional augmentation and amendment are suitably applied for high-efficiency environmental cleaning even with 100 % pollutant removal in a short time (Gangola *et al.*, 2015). However, the success rate of phytoremediation depends on the plant selection. There are certain plants having this natural ability to uptake the toxic pollutants and contaminants from air, soil and

water. However, the most desirable characters are those plant species that have high biomass and are extremely tolerant to high concentrations of different harmful contaminants present in the environment. The convenient plant species have been found in polluted areas (Farraji *et al.*, 2020), such as plants growing in abandoned mine sites. Suitable plant selection for phytoremediation extremely depends on the nature and concentrations of the contaminants (Pilon-Smits, 2005), period of the area (Hutchinson *et al.*, 2001), its intensity (Cunningham *et al.*, 1996), rate of volatilization (Ghosh and Singh, 2005) and biodegradation (Joner and Leyval, 2003). Furthermore, the selection of a suitable green technology for specific pollution is essential for effective phytoremediation. The main objective of this review work is to highlight the different aspects of phytoremediation, its merits and demerits and their efficiency in environmental clean-up.

Different techniques of phytoremediation: There are different methods of phytoremediation where specific plants are used to remove the toxic pollutants from the environment.

Phytoextraction: Phytoextraction, also called Phytoaccumulation, involves absorbing the contaminants from the environment into the plant biomass. In this process, plants are used to absorb, translocate and store toxic contaminants from a soil matrix into their root and shoot tissues for safely removing them from the area. The contaminants are thus eliminated from the environment without degrading them. This is particularly useful for removing metals from soil and, in some cases; the metals can be recovered for reuse, by incinerating the plants, in a process called Phytomining.

Phytostabilization: Phytostabilization, also called Phytosequestration or Phytoimmobilization involves plant-mediated immobilization of organic wastes into the soil matrix, thereby reducing their bioavailability. The process works by reducing the mobility of organic pollutants into the environment and preventing them from entering the food chain, thus stabilizing them. This technique also has the advantage of preventing humans from inhaling dust that may be hazardous to their health.

Phytovolatilization: Phytovolatilization involves using specific plants to absorb the pollutants, after which the contaminants are transformed and volatilized into the atmosphere from the leaves. In this process, the pollutants are converted to highly volatile and less toxic substances and thus eliminated from the nature by releasing them into the atmosphere. This process is driven by the high evapotranspiration rate of plants. Initially the plants volatilize the organic contaminants, especially the volatile organic compounds (VOCs). For example, hybrid poplar trees are successfully used to volatilize trichloroethylene (TCE), thus converting it to chlorinated acetates and CO_2. Certain plants can volatilize metals such as Se by converting into dimethylselenide [$Se(CH3)_2$]. In this aspect, genetic engineering has gained success in volatilizing specific contaminants by using plants.

Phytodegradation: Phytodegradation involves the use of enzymes for degrading the harmful organic pollutants like herbicides or trichloroethylene by either releasing them from roots or via metabolic processes of plant tissues. This can occur both inside or outside the plants as the plants can also secrete the enzymes outside. In phytodegradation, the plant parts absorb the various toxic contaminants and metabolize them to less toxic substances. However, the sites of biotransformation vary depending on the type of plants, such as the process can happen in roots, stems or leaves. Poplar trees are frequently used in phytodegradation of toxic organic compounds.

Phytotransformation: In this process, the harmful chemical substances in the environment are modified due to plant metabolism, because of which they are either inactivated or degraded or immobilized. The technique involves converting the complex molecules into simpler ones, which are comparatively less toxic, and then the plant tissues can absorb these simpler ones.

Phytostimulation: Phytostimulation is the process where the enzymes in the plant rhizosphere are activated by microorganisms, thus leading to bioremediation. The event occurs in the area around plant roots. This process is also known as Rhizosphere degradation or Rhizodegradation or Rhizosphere bioremediation. Phytostimulation can also involve aquatic plants supporting active populations of microbial degraders, as in the stimulation of atrazine degradation by hornwort.

Phytorhizofiltration: Phytorhizofiltration, also known as Rhizofiltration, use roots and tissues of plants as a filter to absorb the organic pollutants from water streams or groundwater and store contaminants from an aqueous growth matrix for easily eliminating them. Here, the plant roots filter the water to avoid the contaminants from mixing into the water streams or groundwater. This also helps in minimizing the movement of pollutants in the soil.

Phytohydraulics: In this process, the deep-rooted trees are used to draw like a pump and sequester or degrade the pollutants of the groundwater contaminants coming near their roots, thus restricting their movement in clean zones.

Table 1: Comparison between different phytoremediation technologies on various groups of contaminants

Technology	Action on Contaminants	Main Type of Contaminant	Vegetation
Phytostabilization	Retained *in situ*	Organics and metals	Cover maintained
Phytodegradation	Attenuated *in situ*	Organics	Cover maintained
Phytovolatilization	Removed	Organics and metals	Cover maintained
Phytoextraction	Removed	Metals	Harvested repeatedly
Phytofiltration	Retained *in situ*	Metals	Cover maintained

Phytoremediation is effective in the remediation of many different types of contaminants from the environment such as heavy inorganic metal pollutants like Arsenic (As), Antimony (Sb), Gold (Au), Lead (Pb), Molybdenum (Mo), Mercury (Hg), Nickel (Ni), Silver (Ag), Zinc (Zn); other radionuclides include Uranium, Caesium-137, Strontium-90, Anthracene, Atrazine, Trichloroethylene (TCE), Pyrene, Toluene, Phenol, Trinitrotoluene (TNT) and other contaminants from Polycyclic aromatic hydrocarbons (PAHs), Total petroleum hydrocarbons (TPH), Polychlorinated biphenyls (PCBs), herbicides, pesticides and certain volatile organic compounds which include chlorinated solvents. Some of the types of plants successfully used in phytoremediation are Alfalfa, hybrid Poplar trees, Tobacco, Spinach, Corn, Stonewort, Black willow, Blue-green algae, Duck weed, Arrowroot, Sudan, Rye, Bermuda, Alpine bluegrass, yellow and white water Lillies etc.

Applications of Phytoremediation: Most of the phytoremediation methods are commercially successful and developing rapidly in research areas.

SOIL-Phytoextraction, Phytostabilization, Phytostimulation, Phytovolatilization, Phytotransformation, Phytoimmobilization and Phytodegradation.

AIR- Green belts with suitable tree species whose canopy serve as sink for contaminants.

WATER- Rhizofiltration, Hydraulic Barriers, Vegetative Caps and Constructed Wetlands.

OTHERS USES- Riparian buffer zones Storm water retention bioengineering for erosion control etc.

Advantages of Phytoremediation:

- Phytoremediation is much affordable in comparison to traditional processes both in situ and ex situ, in large areas.
- The use of plants can be easily monitored in this process, which reduces erosion and metal leaching in the soil.
- It largely depends on solar energy.
- It preserves the topsoil, thereby maintaining the fertility of soil and plant phytochemicals.
- There is possibility of recovery and re-use of valuable metals.
- Phytoremediation sites are low maintenance and more aesthetically pleasing.
- It involves no noisy equipment.
- It is a harmless method because it is eco-friendly using naturally occurring species, thus conserving the environment in its natural state.

Disadvantages of Phytoremediation:

- The process is not successful for sites with high contaminant concentrations.
- It is slower than conventional methods and requires a long-term commitment.
- It is seasonally effective and does not work through the winter.
- It is not always possible to prevent the contamination of groundwater.
- Bio-accumulation of contaminants from plants can enter the food chain directly through the primary consumers.

CONCLUSION:-

Therefore, in conclusion it can be said that despite few disadvantages, phytoremediation is being successfully used to treat a wide range of contaminants in a broad range of environments. The Environment Protection Act (EPA) uses phytoremediation for many reasons. It takes advantage of natural plant processes and requires less equipment and labour than other methods since plants do most of the work. The specific plant species and trees that are used in this technology can also help in controlling soil erosion, thus making an area much attractive, noise free zone, and improve the surrounding air quality. It is clear that in future days, phytoremediation would be applied increasingly for removing the toxic pollutants from contaminated sites or from process wastes. It is to be noted that the interactive activities of the microorganisms, soil, and plants along with the different techniques of phytoremediation need to be explored further. Additionally, the plants and microbes should be modified genetically so that they may have greater potentiality, however, their consequences on overall environment needs to be investigated before commercialization. The theoretical research of phytoremediation aims at integrating engineering applications in future. With increasing legislation, phytoremediation will be used as a viable alternative to chemical treatment. Phytoremediation is now effectively used across many places all over the country. Phytoremediation offers a slow but low cost, low-risk, attractive and solar energy driven clean-up technique of remediation that is well regarded by the public and has to be fully established before it can be commercially available. Research findings clearly indicate that this is a feasible and novel technology that holds greater promise for future. However, further research is obligatory to observe the economic and ecological competences of phytoremediation.

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