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NANOPHYTOREMEDIATION : A NEW TOOL FOR HEAVY METAL REMEDIATION

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ABSTRACT

A major issue on a worldwide scale is heavy metal pollution, which is brought on by many activities such as improper farming practices, unregulated dumping of industrial and municipal waste, etc. Heavy metals can harm the ecology since they are not biodegradable. The most serious hazard to soil and water resources is heavy metal contamination in the soil. In agricultural areas, toxic heavy metals, including cadmium, arsenic, lead, chromium, mercury, etc., build up and enter the food chain, damaging human health. There are several techniques for removing heavy metal pollution, but each has benefits and drawbacks. The employment of a biological agent in pollutant degradation is referred to as bioremediation, and the process is known as phytoremediation if plants are involved. Hyperaccumulating plants may be utilized in phytoremediation to clean up metal-polluted areas. This innovative, cost-effective, long-lasting, and promising tool for heavy metal detoxification. Nanomaterials are a viable option for rehabilitating polluted soils because they have large surface areas, many active surface sites, and high adsorption capabilities. A more effective method of removing heavy metals from soil combines phytoremediation with nanotechnology. Several nanomaterials have been developed for environmental applications. According to research, nanophytoremediation was more effective than phytoremediation or nanoremediation for the deterioration of heavy metals contaminated soil.

INTRODUCTION

The science of remediation involves removing or reducing contaminants from the environment by chemical or biological methods. The use of extremely small manufactured particles known as nanoparticles (NPs) or ultrafine particles characterizes nanotechnology, the science of producing and utilizing "petite" particles with dimensions in the 10^9m. Contrarily, phytoremediation is a component of bioremediation that employs higher plants to remove, transfer, stabilize, and/or destroy contaminants from soil, surface water, sediments, and groundwater, including volatile and semi-volatile organic compounds, explosives, solvents, pesticides, radionuclides, metals, and crude oil and its byproducts (Sarkar et al. 2021; Ulaganathan et al., 2022). Phytoremediation is derived from the Greek word "phyto," which refers to a plant, and the Latin suffix "remedium," which means to cure or repair. Phytoremediation, often known as natural green biotechnology, is a flexible method that uses plants to clean contaminated soils, pollutants, deposits, and groundwater in an economical and environmentally friendly manner. A combination method called nanophytoremediation is used to clean up polluted environments.

PHYTOREMEDIATION MECHANISMS

A green method that is successful in removing various toxins from the environment is phytoremediation. It is inexpensive, efficient, and environmentally safe. The following list includes several kinds of phytoremediation mechanisms:

1. Phytodegradation: In this phytoremediation method, pollutants are digested or biotransformed inside the tissues of plants.
2. Rhizosphere biodegradation: Plant roots release natural secretions such as enzymes. By doing this, nutrients are provided to the rhizosphere, and the soil surrounding the roots, and microorganisms help the biological breakdown of pollutants.
3. Phyto-stabilization: The plant creates chemical substances that can immobilize, precipitate, or sequester pollutants. Also known as phyto-sequestration. Plants absorb water-soluble organic pollutants and release them into the atmosphere when they transpire through their leaves.
4. Phytoaccumulation (or phytoextraction): Plant roots absorb pollutants, mineral salts, and water and store them in the stems and leaves of the plant. Phytomining is a safe disposal method used for accumulated hazardous materials.
5. Rhizofiltration: This method of water flow filtration involves hydroponics. To irrigate plants, contaminated groundwater is pushed to the surface. This can therefore be applied to ex-situ groundwater treatment. Plants are picked and disposed of after being saturated with pollutants due to phytoaccumulation in the roots.
6. Phytohydraulics (hydraulic control): Many trees have extensive roots that reach deep into the groundwater and absorb a lot of water, a process known as phytohydraulics. Pesticides, hazardous herbicides, fertilizers, explosives, and radioactive substances are among the pollutants in the water table that are reduced to, or completely removed from, the groundwater.

BIOSYNTHESIS OF NANOPARTICLES FROM PLANTS

The development of new, stable, affordable, and environmentally friendly materials has increased significantly because of the biological synthesis of NPs. Although there are several traditional techniques for producing NPs, the biological route is preferable because of its simplicity, quick synthesis, controlled toxicity, control over size properties, cheap cost, and eco-friendly approach. The production of NPs can be carried out by vascular plants and microorganisms, including bacteria, yeasts, algae, fungi, and actinomycetes. The benefit of extracellular enzyme secretion is the ability to produce significant amounts of NPs with a size range of 100–200 nm in a reasonably pure form, distinct from other cellular proteins; the resulting NPs are then further purified by filtering. Metal compounds are often reduced into their respective NPs by microbial enzymes or plant phytochemicals with antioxidant or reducing capabilities. Water soluble phytochemicals reduce metal ions considerably faster than fungi and bacteria, which need a much more extended incubation period. A possible "biofactory" for synthesizing NPs such as gold, silver, platinum, palladium, titanium, titanium dioxide, magnetite, cadmium sulfide, and others is thought to be bacteria.

APPLICATIONS OF NANO-PHYTOREMEDIATION

NPs are widely employed to remove organic pollutants and biological and chemical contaminants. These nanoparticles are used in various industries, including biomedicine, electronics, agriculture, pharmaceuticals, cosmetics, environment, food and beverage, surface coating, and polymers, due to their special features. The capacity of NPs to absorb significant amounts of pollutants or catalyze processes at a much quicker rate due to their huge surface area and high surface energy allows them to use less energy during degradation and assist the release of contaminants (Verma et al. 202; Gul et al. 2022). In other words, this technology looks at ways to reduce pollution by preventing it from forming or releasing it into the environment. The ability to access previously inaccessible places because of particle size reduction encourages in situ rather than ex situ remediation.

The ability to access previously inaccessible locations thanks to the nanosized particles also encourages in situ rather than ex situ repair. The construction of sensors with high selectivity, sensitivity, and specificity is made possible by NPs' capacity to be coated with a variety of ligands and to change the surface area to volume ratio by modifying their forms. The possible environmental advantages of nano-phytoremediation may be broadly categorized into three groups: treatment and remediation, sensing and detection, and pollution prevention. Nano-bioremediation removes or reduces environmental contaminants from polluted locations, such as heavy metals, organic and inorganic pollutants, utilizing nanoparticles (NPs) produced by bacteria, fungus, and algae (Verma et al. 202; Arisekar et al., 2022). The most used remediation tool is iron NPs. Iron plays a crucial part in removing environmental toxins because of its reducing abilities as an electron donor. It may be used to remediate any contamination that can be broken down by reduction since it is a potent reductant. Iron oxides, manganese oxides, cerium oxides, titanium oxides, or zinc oxides are engineered nanoparticle substances that absorb metals and metalloids very well (Sarkar et al. 2021). They are useful for remediating polluted soils because of this affinity, a large number of active surface locations, and a substantial surface area.

CONCLUSION

The production of nanoparticles by plants is a natural process. Nanophytoremediation is a new and exciting technique that has proved popular due to its present focus on plant research. The biosynthesis of nanoparticles involves several plant groups, as mentioned in this article. The bioaccumulation of toxic nanoparticles in plants can be prevented by researching the creation of metal nanoparticles, their kinds, derivatives, and effects on physiological processes. The toxicity and contamination of metals in crops and medicinal plants may have a significant impact since many nations utilize plants as their major energy source for food and fodder. In general, the existence of nanoparticles, the requirement for biomonitoring environmental trace elements, the physiological impacts of bioelements, and transgenic plants can be employed successfully in nanophytoremediation. Therefore, nanophytoremediation can be used as a complementary biological clean-up approach to maintaining environmental sustainability.

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