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Microbial Bioremediation for Pollutant Mitigation

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Description

Even at low concentrations, heavy metals are dangerous and pose significant exposure risks to animals and humans. Microbial bioremediation is a promising method to mitigate these pollutants from the contaminated water. A variety of methods have been attempted to remove the contaminants from the water and maintain the water's quality. Bioremediation is an innovation that can be utilized in a variety of water and soil conditions because of the adaptability of microorganisms to the elimination of a toxic pollutant. This review provides insight into the sources, distribution, and dangers of toxic heavy metals for humans. Microbial bioremediation for pollutant mitigation from various ecological lattices has received a lot of attention in this review. The focus of this review is on the mechanism of microbial bioremediation in terms of the factors affecting microbes' roles and interactions with pollutants. In addition, newly developed strategies and technologies in the fields of genetically engineered microorganisms and microorganism-aided nanotechnology have demonstrated themselves to be potent bioremediation tools with significant potential for the elimination of water pollutants.

Structural and Functional Characterization

Organophosphate pesticide (OPP) bioremediation has primarily relied on microorganisms, microbial enzymes, and plants ever since the concept of bioremediation was first proposed. In recent years, extensive research has been conducted on these microbes' enzyme systems and genetic makeup. One of the potential candidates for OPP bioremediation is Plant Growth Promoting Rhizobacteria (PGPR), which have been widely used to boost plants' phytoremediation potential. In OPP biodegradation, constructed wetlands have opened up new possibilities for microcosm and mesocosm based remediation methods. By introducing concepts like gene manipulation and editing, expression and regulation of catabolic enzymes and the implementation of whole-cell based and enzyme-based biosensor systems for the detection and monitoring of OPP pollution in both terrestrial and aquatic environments, the application of synthetic biology has added a new dimension to the field of OPP bioremediation. The tools of system biology and bioinformatics have given researchers a lot of information about the genetic, enzymatic, and biochemical aspects of plants and microbes, which has helped them figure out how OPP biodegrades. In terms of OPP biodegradation pathways, metabolite and enzyme structural and functional characterization, enzyme-pollutant interactions, and other topics, structural biology has provided significant conceptual information. As a result, the prospects and challenges of the majority of the advanced and high-throughput strategies used for OPP biodegradation were discussed in this review. In addition, the review provided a comparative analysis of various bioremediation methods and emphasized their interdependence. The review strongly recommended that more than one remediation strategy be used simultaneously or that a combinational approach be used to create an advantageous hybrid method for OPP bioremediation. The ecosystem's long-term viability is seriously threatened by pollution. The rapid rise in environmental pollution is a pressing issue that threatens the livelihoods of people who live on land and in the water. This can be attributed to human-caused and industrial processes, such as mining, which frequently result in the production of acid mine drainage, which is regarded as one of the most disastrous ecological issues. The significant impact on the use of soil and water for both domestic and commercial purposes highlights the urgent need for remediation. In the treatment of AMD contamination, the use of physical, chemical, physicochemical, and thermal methods has been criticized because some of these methods are harmful to the environment and cause site recontamination. In bioremediation, contaminants are broken down by microorganisms in a controlled environment. The various bioremediation techniques used to treat AMD contamination, the factors that influence their application, cost-benefit and environmental impact analyses, difficulties, and prospects of bioremediation technologies for efficient treatment were all critically examined in this study. The study demonstrates that bioremediation has proven to be efficient and can be an environmentally friendly and cost-effective method for the remediation of AMD-contaminated sites. However, it is still difficult to use on a large scale. Bioremediation technologies that can remediate sites with complex mixtures of contaminants that are not evenly distributed in the environment require further study to improve and develop.

Utilization of Microorganisms

Organic and/or inorganic contaminants can have a significant negative impact on the marine food web and human health in coastal environments. It is known that PAHs, HMs, and metalloids have a significant impact on biological systems like cell membranes, organelles, and enzymes, resulting in changes to the cell cycle, carcinogenesis, or apoptosis. These contaminants may remain in the environment for an extended period of time and may be subjected to processes of bioaccumulation and/or bio magnification, both of which raise the likelihood that they will cause harm. Chemical treatments, electrochemical methods, and physical adsorption are typical approaches to the elimination of PAHs and HMs. Sadly, these methods typically generate special waste, are costly, ineffective at low pollutant concentrations, and extremely energy-intensive. Due to several microbial characteristics, including high biodegradation/detoxification efficiency toward several contaminants, high surface area-to-volume ratio, and the capacity to grow at high concentrations of toxic pollutants, the utilization of microorganisms, particularly bacteria, fungi, and microalgae, may be a promising alternative or complementary strategy to such conventional tools. Due to the low carbon footprint of the decontamination process as a whole, microbial-based remediation strategies are also considered to be one of the most environmentally friendly methods. Several mechanisms, including assimilation, intracellular detoxification, and/or co-metabolism mediated by the activity of particular enzymes like oxygenase, dehydrogenase, and ligninolytic enzymes, enable microbes to effectively break down PAHs. It is common knowledge that sorption, leaching, or transformation of HMs by microorganisms is low-cost and highly effective HM bioremediation procedures. In most marine polluted sites, PAHs and HMs co-contaminate each other. Several microbes can work together to remove or detoxify these contaminants through bioleaching, biosorption, and biodegradation, which increases their overall capacity. Microbial secretion of enzymes with useful bioremediation activities under mixed PAHs and HMs contamination is an example of this synergistic approach and of polysaccharides found outside of cells Because they contain a wide variety of polymers and functional groups, EPSs are particularly relevant targets for bioremediation studies because they can simultaneously bind metals, enhancing HM extraction and removal from contaminated matrices, PAH solubilization and enzymatic degradation efficiency.