Opinion

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Microbial Bioremediation: A Feasible Method for Detoxifying Contaminated Sites by Heavy Metals and Pesticides

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Opinion

Industrialization and other human activities pose considerable environmental risks. The sustainable detoxification or conversion of accumulated contaminants has emerged as the primary problem of the present. Bioremediation is a biology-based process in which wastes are recycled into various forms that can be used by other species. Bioremediation techniques are gaining popularity for various reasons, including environmental friendliness and low cost compared to chemical and physical treatments, which are becoming more expensive over time. Environmental microorganisms frequently produce a variety of enzymes that can remove dangerous toxins by using them as a substrate for development and growth. As a result, microbes are seen as increasingly appealing as an alternate technique for overcoming various obstacles. Environmental microorganisms frequently produce a variety of enzymes that can remove dangerous toxins by using them as a substrate for development and growth. Microbial enzymes, by their catalytic reaction mechanism, can break down and remove hazardous environmental contaminants, transforming them into non-toxic forms. Hydrolases, lipases, oxidoreductases, oxygenases, and laccases are the most common types of microbial enzymes that may break down the most hazardous environmental pollutants. In addition, one of the most essential aspects of bioremediation technology is in-situ treatment, which limits the likelihood of toxins spreading to other sites. Heavy metal and pesticide pollution have become an unavoidable element of today's industrialized environment, infiltrating all ecosystems. Metal and pesticide contamination has challenged the stability of the ecosystem as well as the health of living creatures due to their persistent nature, recalcitrance, high toxicity, and biological enrichment (Cao et al., 2023).

This review focuses on the applications of potential microorganisms in the field of bioremediation of different contaminants dwelling in the environment (Figure 1). Bioremediation is the use of live organisms to mitigate the harmful effects of contaminants that are harmful to living organisms. Pollutants can be remedied by a variety of living organisms; fungi, bacteria, algae, and their oxidative biocatalysts are important in recycling refractory biomolecules and xenobiotics. Plants also help to eliminate contaminants naturally, transgenically, or in collaboration with rhizosphere bacteria. Microorganisms are linked to all living things and play an important role in biogeochemical cycling, constituting the foundation of a functional ecosphere. Temperature, moisture, humidity, oxygen, pH, and nutrition are all environmental elements that influence microbial activity. The variation in environmental conditions from one location to the next has resulted in a great diversity of microorganisms. One reason organisms use xenobiotic substances is to meet nutrient demands. They cannot, however, rely only on xenobiotics for growth and thus require additional C and N sources. They can then modify or degrade contaminants through co-metabolism. Catabolic genes in microor-

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ganisms promote their ability to process metabolic reactions for the breakdown and transformation of environmental toxins into non-toxic ones. Currently, businesses emit a wide spectrum of organic and inorganic pollutants that harm the environment and humanity.

Figure 1: Microbes dwelling in the environment are decontaminating the waste generated by various means.

Organic pollutants include pesticides, phenols, and dyes, whereas inorganic pollutants include toxic heavy metals. Heavy metals generate oxidative stress in cells and tissues by affecting cellular components and organelles. Pesticide poisoning causes various illnesses in living beings and is also damaging to non-target organisms. Pesticides used indiscriminately can also have a negative influence on biodiversity. To remove heavy metal ions from contaminated areas, technologies such as membrane filtration, ion exchange, and chemical precipitation have been developed, which convert heavy metal pollutants to inactive states. Similarly, standard pesticide-polluted site decontamination technologies such as landfilling, chemical modification, incineration, composting, and so on are being used. Due to the limitations of these methods, such as secondary pollution induction, low-density sludge generation, limited activity in acidic environments, and so on, researchers have focused their attention on using bioremediation technologies that are environmentally friendly, low cost, and highly efficient in pollutant degradation. The utilization of diverse microbiological agents, such as bacteria, fungi, yeasts, and algae, has gotten a lot of interest around the world in order to remediate various matrixes contaminated with heavy metals and persistent organic pollutants. Microbial remediation is the most appropriate and favoured option in these times of environmental and economic problems, particularly in developing nations. A study found that using bioremediation methodologies for the remediation of contaminated soils saved 50-60% more money than other traditional methods.

Several researchers have isolated and characterized potential microbial species for the removal of heavy metals and pesticides from industrial waste. It is worth noting that microbial remediation is regarded as one of the safest, most advantageous, dependable, and efficient techniques of removing hazardous heavy metals and pesticides. Microbes are ubiquitous in nature and can tolerate harsh environmental conditions, making them ideal for the breakdown of harmful pollutants. Because of their high sensitivity for a wide range of toxins as well as functioning at lower concentrations, microbial remediation is an excellent alternative. For example, microbial biosorption of heavy metals has proven to be particularly effective for polluted site cleanup. Furthermore, because microorganisms are tiny in size, microbial biomass has a higher surface area to volume for adsorption than other remediation approaches, including phytoremediation. Microbes have a complex structure which accelerated the bioabsorption of toxic compounds. When opposed to phytoremediation, another advantage of using microbes for remediation is their fast-multiplying ability, which can be stimulated by the provision of appropriate nourishment or modified bacteria. Under various environmental conditions, systemic biology [SB] allows for the study of microbial behaviour at the community level. Using the SB technique, vital information for metabolic engineering of microorganisms for enhanced bioremediation capability can be gained. Omics techniques would aid in the discovery of new bacteria for bioremediation. Multi-omics research will aid in the development of new ideas and theories for bioremediation of polluted environments.

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