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Bioremediation: An Approach to Sustainable Development

Shipra Mohan Tripathi

Department of Biotechnology, Utkarsh School of Management and Technology (Affiliated to MJP Rohilkhand University), Bareilly, U.P., INDIA

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ABSTRACT

With the increasing human-induced activities a wide range of aquatic and terrestrial habitats are being contaminated which requires an eco-friendly technology for the sustainable development and management of the environment. Bioremediation is now a day's one of the widely used and popular approach as an alternative to primitive methods for the treatment of waste materials and sources by degrading the contaminants with the help of microbial activity mediated by various bacterial strains. Bioremediation can be broadly divided into three types i.e. Biostimulation, Bioaugmentation and Intrinsic Bioremediation. These bioremediation type marks their action on different pollution task such as degradation of organic wastes with the help of microbes, clean-up of dissolved soil and water contaminants, toxins, heavy metals and oils. Bioremediation is governed by microorganisms which under aerobic and anaerobic reaction create certain enzymatic conditions to eliminate, degrade, and detoxify the hazardous wastes and pollutants. The strategy followed by bioremediation stimulates the basic organic mechanism in order to cleanse both contaminated soil and the groundwater. The consequential threat to ecology is the occupancy of heavy metals in the water bodies which is considered as the enigmatic worldwide environmental distress to deal with. This review discusses about most recent developmental techniques of bioremediation, microbial mode of action to break down different pollutants, and the future aspects of bioremediation in order to decrease the load of pollution from the world.

Key words: bioremediation; microorganisms; pollutants; sustainable development; biostimulation; bioaugmentation

1) INTRODUCTION

The global industrialization has adversely affected the environmental health by evolving pollution of the freshwater and topsoil. Fresh water quality has declined abruptly through the human activity such as mining, disposal of toxic metal effluents from steel industries, e-waste (Lithium-ion batteries, lead acid batteries, etc.) and electric and nuclear power plants. Various toxic effluents like petroleum, polythenes, and trace metals which are disposed or released to open dump-yards/ water bodies proves to be calamitous for the environment. Some pollutants like heavy metals exist in nature in the Earth's crust and are quite strenuous to disintegrate. Because of their high metabolic ability microorganisms are thoroughly distributed on the biosphere as they can easily grow in a wide range of environmental conditions. Microorganism's shows a wide range of nutritional versatility when it comes to their survival, which can be further exploited for biodegradation of pollutants. Microorganisms act as crucial pollutant removal tool from soil, water, and sediments as they have advantage of low-cost effect over other remediation procedural protocols [1] Microorganisms help to restore the natural surroundings and prevent further pollution. There are certain pollutants (activated wastewater sludge) that are unsusceptible to biodegrade easily. The circumstances responsible for the resistance of pollutants such as high toxicity, low water solubility; low bioavailability, high stability and low biodegradability show a dominant effect on the microbial activity in degrading the industrial wastewater. This problem of microbial resistance can be overcome by the bioaugmentation i.e. introduction of specific microorganisms which have the ability to biodegrade intractable molecules/pollutant content present in the contaminated environment [2]. Bioremediation research mainly focuses on bacterial processes (both aerobic and anaerobic) but now a day's fungal and algal strains are being employed to treat the contaminants and toxins released from industries. This review addresses the recent developments and upgrades technological information about bioremediation strategies incorporating eco-friendly detoxification and the effective degradation of various organic and inorganic contaminants to overcome the environmental pollution [3].

2) FACTORS AFFECTING MICROBIAL BIOREMEDIATION

Bioremediation is the process where various chemicals and physical wastes from the environment are eliminated

* Corresponding Author: **Shipra Mohan Tripathi**
Email address: shipra.monu09@gmail.com

through the employment of bacteria, fungi and plants when methods like degrading, removing, altering, immobilizing, or detoxifying are applied. To degrade the desired pollutant microorganisms facilitates with their biochemical reactions which are carried through their enzymatic pathways [4]. On the mode of their nutrition and to generate energy from the waste compounds, produce toxic metabolites, microorganisms react against those pollutants. There are various factors that can easily effects the efficiency of bioremediation such as; the chemical nature and concentration of pollutants, the physicochemical characteristics/inhibitory environmental conditions (type of soil, temperature, pH, the presence of oxygen or other electron acceptors, and nutrients, depletion of preferential substrates), and their availability to microorganisms [5]. Sometimes the source of waste compounds gets degraded before any microbial reaction is due to zero contact between the two. The reason behind this source depletion is the improper distribution of microbes and pollutants in the environment. Being a complex system it is very difficult to control and optimize the process of bioremediation.

3) PRINCIPLE OF BIOREMEDIATION

The basic principle of bioremediation is based on the process where biological degradation of organic wastes are acclaimed under superintended settings to an innocuous state, or lower levels of concentration limits accustomed by regulatory authorities. The governance of the enzymatic activity leads microorganisms to be opted for the task of contaminant blow-up. Bioremediation encourages the microorganisms by providing adequate amount of nutrients and essential chemicals compounds to boost up their metabolic reaction in order to degrade/ detoxify the hazardous substances from the environment. All metabolic reactions are regulated by enzymes. There are various classes of enzymes such as: oxidoreductases, hydrolases, lyases, transferases, isomerases, translocases and ligases. Most of the enzymes shows a wide-range of degradation ability when they have specific substrate affinity. Bioremediation proves to be effective when microorganisms enzymatically manipulate the pollutants effect and follows the enzyme-substrate complex formation to convert the toxic compounds into harmless products. Bioremediation is a natural process and is widely influenced by the introduction of living things (microbes) and fertilizers.

Bioremediation is principally based on biodegradation, and it refers to the removal and conversion of organic toxic pollutants into non-toxic or natural compounds such as carbon dioxide, water, inorganic compounds which are safe for human, animal, plant and aquatic life [6]. There are various techniques and pathways that have been interpreted for the biodegradation of number of organic compounds and sometimes the degradation is achieved through the other bacterial strains which are highly specialized and comes under the category of Archaea bacteria (special bacterial strains works in adverse conditions) and an aerobic bacterium (works in the absence of oxygen).

4) FUTURE ASPECTS

In the recent studies it was found that bioinformatics and biostatistics analyses were conducted on previous bioremediation data to evaluate and justify the need for genetically modified organisms. GMO's will automatically possess the earlier identified efficient metabolic processes, enzymes, genes, or operons capable of bioremediation specific pollutants with enhanced biodegradation ability [7].With the help of new emerging molecular techniques such as genomics, proteomics, and metabolomics it will be highly advantageous to explore the other formulations in bioremediation for the possible solutions to target the specific pollutants. Areas to be explored under bioremediation are:

a. Identification and comparison of gene and protein sequences for the elimination of contaminants.
b. Phylogenetic studies and the diversity among the important gene and protein sequences involved in bioremediation.
c. Implementation of specific genes in microbial biotechnology for further gene manipulation.

Employment of various microbial consortiums rather than the single microbial consortium prove to be advantageous approach in bioremediation, as it will emphasize the presence of divergent entity for the utilization of different substrate, in order to increase the rate of microbial biodegradation consequently.

5) CONCLUSION

Biodegradation is one of the effective methods of remediating, cleaning, managing and recovering technique to overcome from the polluted environment with the implementation of microbial activity. The whole degradation unnecessary waste substances/compounds is dependent on chemical process and reactions taking place within the biological agents, adequate essential nutrient supplements, unwanted external abiotic conditions (aeration, moisture, pH, temperature), and low bioavailability of the pollutant. Biodegradation in natural condition with the involvement of these certain factors is highly affected and tends to become unsuccessful. For the effective bioremediation process it is necessary to have the favourable environmental conditions to support the microbial growth and activity. On the different sites globally, bioremediation has been implemented and a varying degree of success has been observed. There are certain disadvantages of this technology but also the advantages are greater which are the evident from the number of sites where the bioremediation techniques has been employed and due to this its popularity has aroused within the time [8]. From the different sites a diverse species/strains were explored which were found to be effective in degradation of various toxins

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