An Analysis of Role of Microorganisms in Bioremediation

Dr. Santosh Kumar Singh, Assistant Professor
Department of Health & Allied Science, Arka Jain University, Jamshedpur, Jharkhand, India
Email Id-dr.santosh@arkajainuniversity.ac.in

ABSTRACT: Bioremediation is a biological process for recycling wastes into a form that other species may utilize and reuse. The globe is now dealing with many forms of environmental degradation. Microorganisms are a critical component of a major alternative approach for overcoming obstacles. Microorganisms can live in every location on the biosphere due to their incredible metabolic activity, and they can thrive in a wide variety of environmental circumstances. Microorganisms have a wide range of nutritional capacities, which makes them ideal for bioremediation of environmental contaminants. Through the all-inclusive and activity of microorganisms, bioremediation is heavily engaged in the degradation, eradication, immobilization, or detoxification of various chemical wastes and physical dangerous elements from the environment. Degrading and converting pollutants such as hydrocarbons, oil, heavy metals, pesticides, dyes, and other chemicals is the fundamental concept. Because it is carried out in an enzymatic manner by metabolizing, it has a significant contribution to the solution of many environmental issues. The pace of deterioration is determined by two kinds of factors: biotic and abiotic environments. Various techniques and strategies are now being used in the domain in various parts of the globe. Biostimulation, bioaugementation, bioventing, biopiles, and bioattenuation are only a few examples. Because each bioremediation method has its own unique application, it has its own set of benefits and drawbacks.

KEYWORDS: Bacteria, Biodegradation, Bioremediation, Contaminants, Microorganisms.

1. INTRODUCTION

Microorganisms are extensively dispersed throughout the biosphere due to their remarkable metabolic abilities and their capacity to thrive in a broad variety of environmental circumstances. Microorganisms' nutritional flexibility may also be used for pollution biodegradation. Bioremediation is the name for this kind of procedure. It is carried out based on the capacity of some microbes to convert, alter, and use harmful contaminants in order to generate energy and biomass [1]. Bioremediation is a microbiologically well-organized procedural activity that is used to break down or convert contaminates into less hazardous or harmless elemental and compound forms, rather than just collecting and storing them. Bioremediators are biological agents that are employed in the bioremediation of polluted areas. Prime bioremediators include bacteria, archaea, and fungus. The use of bioremediation as a biotechnological method using microorganisms to solve and remove the risks of numerous pollutants from the environment via biodegradation. The phrases bioremediation and biodegradation are increasingly interchangeable.

Microorganisms play an important role in pollution removal in soil, water, and sediments, owing to their advantages over conventional remediation procedures. Microorganisms are helping to restore the natural environment and avoid pollution [2]. The goal of this study is to convey current trends in the application/role of microorganisms in bioremediation, as well as to provide essential background information to fill in gaps in this subject area. Microorganisms are eco-friendly and provide important genetic material to address environmental concerns, therefore it's a popular study field right now.

1.1 Factors affecting microbial bioremediation:

Bioremediation is the process of bacteria, fungus, and plants degrading, eliminating, modifying, immobilizing, or detoxifying different chemicals and physical pollutants from the environment. Microorganisms are engaged because their enzymatic pathways serve as biocatalysts, allowing biochemical processes to proceed more quickly and destroy the targeted contaminant. Only when microorganisms have access to a range of materials components to assist them produce energy and nutrients to grow new cells can they act against pollution? The chemical type and concentration of contaminants, as well as the physicochemical properties of the environment and their availability to microorganisms, all influence bioremediation efficacy [3]. Because bacteria and contaminants do not come into touch with each other, the rate of deterioration is impacted. Furthermore, microorganisms and contaminants are not evenly distributed across the environment. Due to a variety of variables, managing and improving bioremediation processes is a complicated system. The presence of a microbial population capable of degrading pollutants, the availability of contaminants to the microbial population, and environmental variables (type of soil, temperature, pH, the presence of oxygen or other electron acceptors, and nutrients) are all aspects to consider.

1.1.1 *Biological factors:*

Competition between microbes for restricted carbon sources, antagonistic interactions between microorganisms, and predation of microorganisms by protozoa and bacteriophages are all biotic factors that influence the breakdown of organic molecules. The pace of contamination degradation is often determined by the contaminant concentration as well as the quantity of "catalyst" present. The quantity of "catalyst" in this context refers to the number of organisms capable of metabolizing the contaminant, as well as the number of enzymes(s) generated by each cell. The pace of contaminant breakdown may be sped up or slowed down depending on the expression of certain enzymes by the cells. Furthermore, specific enzymes involved in contaminant metabolism must be included, as well as their “affnity” for the contaminant and availability of the contamination. Mutation, horizontal gene transfer, enzyme activity, interaction (competition, succession, and predation), its own development until critical biomass is achieved, population size and composition are all covered here [4].

1.1.2 *Environmental factors:*

Possible interactions throughout the procedure are determined by the metabolic characteristics of the microorganisms and the physicochemical features of the targeted pollutants. The actual success of the contact between the two, on the other hand, is determined by the ambient circumstances at the interaction site. pH, temperature, moisture, soil structure, solubility in water, nutrients, site characteristics, redox potential, and oxygen content, lack of trained human resources in this field, and Physico-chemical bioavailability of pollutants (contaminant concentration, type, solubility, chemical structure, and toxicity) all influence microorganism growth and activity. The kinetics of deterioration are determined by the variables mentioned above [5]. Biodegradation may occur at any pH; however, in most aquatic and terrestrial environments, a pH of 6.5 to 8.5 is usually optimum for biodegradation. Moisture affects the pace of contaminant metabolism by affecting the types and quantities of soluble materials available, as well as the osmotic pressure and pH of terrestrial and aquatic systems. The majority of environmental variables are mentioned below.

A) *Availability of nutrients:*

Nutritional input affects the necessary nutrient balance for microbial growth and reproduction, as well as the pace and efficiency of biodegradation. By adjusting the bacterial C: N: P ratio, nutrient balancing, particularly the delivery of important nutrients such as N and P, may enhance biodegradation efficiency. Microorganisms need a variety of nutrients, including carbon, nitrogen, and phosphorus, to live and continue their microbial activity. The amount of hydrocarbon breakdown is similarly limited at low concentrations. In cold settings, adding an adequate amount of nutrients is an effective approach for boosting microorganism metabolic activity and therefore biodegradation rate. The availability of nutrients limits biodegradation in aquatic environments. Oil-eating bacteria, like other organisms, need resources for optimum growth and development. These nutrients are found in the natural environment, although in little amounts [6].

B) *Temperature:*

Temperature is the most significant physical element in influencing the survival of microbes and the composition of hydrocarbons [7]. Oil breakdown by natural processes is extremely sluggish in freezing settings like the Arctic, putting microorganisms under greater strain to clean up the spilt petroleum. Most oleophilic bacteria are metabolically inactive due to the sub-zero temperature of the water in this area, which causes transport channels inside microbial cells to shut down or even freeze the whole cytoplasm, making them metabolically inactive. The metabolic cycle of biological enzymes involved in the degradation process has an optimal temperature and will not be the same at all temperatures. Furthermore, the breakdown of a certain chemical necessitates a specific temperature. Temperature influences microbial physiological characteristics, thus it may speed up or slow down the bioremediation process. Temperature increases the rate of microbial activity, which reaches its maximum at the optimal temperature. It began to drop abruptly when the temperature increased or decreased, ultimately coming to a halt after reaching a certain degree.

C) *Concentration of oxygen:*

Different species need different amounts of oxygen, while others do not. Depending on their needs, the biodegradation rate may be accelerated. Because oxygen is a gaseous need for most living organisms, biological degradation occurs in both aerobic and anaerobic conditions. In most instances, the presence of oxygen may improve hydrocarbon metabolism.

D) Moisture content:

Microorganisms need a sufficient amount of water to flourish. The moisture content of the soil has a negative impact on biodegradation agents.

E) pH:

The pH of a molecule, which is determined by its acidity, basicity, and alkalinity, has an effect on microbial metabolic activity as well as the rate of elimination. The potential for microbial development in soil may be determined by measuring pH. Higher or lower pH values resulted in poor outcomes; metabolic processes are very sensitive to even minor pH alterations.

F) Characterization and selection of the site:

To properly describe the amount and breadth of pollution, sufficient remedial study work must be done prior to proposing a bioremediation solution. At a minimum, this study should include the following elements: thoroughly determining the horizontal and vertical extent of contamination, listing the parameters and places to be sampled and the reason for their selection, and describing the sample collection and analysis techniques to be utilized.

G) Metal ions:

Metals are essential for bacteria and fungi in tiny amounts, but in large amounts, they impede cell metabolism. Metal compounds influence the rate of deterioration in both direct and indirect ways.

H) Toxic compounds:

When toxic nature of certain pollutants is present in high quantities, it may have toxic effects on microorganisms and slow down decontamination. The degree and mechanisms of toxicity differ depending on the toxicants, their concentrations, and the microorganisms exposed. Some organic and inorganic substances are poisonous to the organism being studied.

1.2 Principle of bioremediation:

Bioremediation is defined as the process of biologically degrading organic wastes under controlled circumstances to a benign state or to concentrations below regulatory concentration limits. Because microorganisms have enzymes that enable them to eat environmental pollutants, they are well-suited to the job of contaminant destruction. The goal of bioremediation is to get them to function by providing them with the right nutrients and other chemicals they need to breakdown and detoxify pollutants that are harmful to the environment and living beings. Enzymes are involved in every metabolic process. These include oxidoreductases, hydrolases, lyases, transferases, isomerases, and ligases, among others. Due to their nonspecific and specific substrate affinity, many enzymes have a very broad degradation capability. Microorganisms must enzymatically attack contaminants and transform them to harmless compounds for bioremediation to be successful. Because bioremediation is only successful when environmental circumstances allow for microbial growth and activity, it is often used to manipulate environmental factors to allow for quicker microbial growth and destruction.

Bioremediation happens spontaneously and is aided by the addition of live organisms and nutrients. Biodegradation is the foundation of bioremediation technique. It refers to the transformation of organic hazardous pollutants into innocuous or naturally occurring molecules such as carbon dioxide, water, and inorganic compounds that are safe for humans, animals, plants, and aquatic life. For the biodegradation of a broad range of organic molecules, many processes and routes have been discovered; for example, it occurs in the presence and absence of oxygen.

1.3 Advantage of Bioremediation:

- It is a natural process that takes some time to complete as a suitable waste treatment method for polluted materials like soil. Microbes that can decompose the pollutant and multiply in numbers when it's present. The biodegradative population decreases as the pollutant is degraded. The treatment leftovers are generally innocuous products such as water, carbon dioxide, and cell biomass.
- It takes relatively little effort and may frequently be done on-site without creating significant interruption to regular operations. This also removes the need to transfer large amounts of trash off-site, as well as the possible health and environmental risks that may occur during transit.

- It is employed in a cost-effective procedure since it loses less than other traditional techniques (technologies) for hazardous waste cleanup. Important treatment technique for oil-contaminated areas.
- It also aids in the total annihilation of pollutants; many dangerous chemicals may be converted into harmless products, and this characteristic removes the possibility of future responsibility connected with the treatment and disposal of contaminated material.
- It does not include any potentially hazardous substances. Fertilizers and other nutrients are given to promote active and rapid microbial growth. Typically seen in lawns and gardens. The hazardous compounds are totally eliminated as a result of bioremediation, which converts them into water and innocuous gases.
- Because of their inherent function in the ecosystem, they are simple, labor-intensive, and inexpensive.
- Eco-friendly and long-lasting.
- Contaminants are eliminated rather than merely transported to other medium in the environment.
- Non-intrusive, possibly enabling site use to continue.
- Effective method of remediating natural ecosystems from a variety of contaminants and acting as environmentally beneficial alternatives.

1.4 Disadvantage of Bioremediation:

- It is only applicable to biodegradable chemicals. Not all chemicals can be completely degraded in a short period of time.
- Some people are concerned that biodegradation products would be more persistent or hazardous than the parent chemical.
- Biological processes are often extremely individualized. The existence of metabolically competent microbial populations, adequate environmental growth conditions, and optimum amounts of nutrients and pollutants are all important site variables.
- Extrapolating from bench and pilot-scale research to full-scale field operations is difficult.
- Bioremediation methods that are suitable for locations with complex combinations of pollutants that are not uniformly distributed in the environment need research to develop and design. Contaminants may exist in the form of solids, liquids, or gases.
- It takes far longer than alternative treatment methods like excavation and soil removal or cremation.
- Regulatory ambiguity about appropriate bioremediation performance requirements persists. Because there is no universally recognized definition of "clean," assessing the efficacy of bioremediation is difficult.

2. LITERATURE REVIEW

Mary Kensa V discussed Bioremediation in which the author explained how Bioremediation is a cutting-edge technique that uses natural biological processes to completely remove toxic contaminants from the environment. Any method that involves the use of microorganisms, fungi, green plants, or their enzymes to restore the natural environment after it has been contaminated. In situ and ex situ bioremediation technologies are the two types of bioremediation technologies. Ex situ bioremediation involves removing contaminated material from the site to be treated elsewhere, whereas in situ bioremediation involves treating the contaminated material on-site. Bioventing, landfarming, bioreactor, compositing, bioaugmentation, rhizofiltration, and bio-stimulaiton are some examples of bioremediation technologies. Bioremediators are microorganisms that perform the function of bioremediation. (bioaugmentation). However, not all contaminants are easily treated by microorganisms in bioremediation. Heavy metals such as cadmium and lead, for example, are not easily absorbed or captured by organisms, and mercury assimilation into the food chain may exacerbate the problem. This paper explains what bioremediation is, the principles of bioremediation, the factors of bioremediation, strategies, types, genetic engineering approaches, bioremediation monitoring, and bioremediation advantages and disadvantages [8].

Okpokwasili G et al. discussed Bioremediation techniques in which they explained how Increased human activity on energy reserves, hazardous farming methods, and fast industrialization have all contributed to an increase in environmental contamination over the last several decades. Heavy metals, nuclear wastes, pesticides, greenhouse gases, and hydrocarbons are among the contaminants that cause environmental and public health problems owing to their toxicity. Because of its environmentally favorable characteristics, bioremediation of contaminated areas has proved to be efficient and dependable. Bioremediation may be done ex situ or in situ, depending on a variety of variables such as cost, site features, and the kind and quantity of contaminants. Ex situ methods seem to be more costly than in situ techniques in general, owing to the extra costs associated with excavation. However, when doing in situ bioremediation, the expense of on-site equipment installation and the difficulty to properly see and manage the subsurface of contaminated areas are significant issues. As a result, selecting the right bioremediation method to successfully decrease pollutant concentrations to safe levels is critical to a successful bioremediation project. Furthermore, biostimulation and bioaugmentation are two key methods to enhancing bioremediation, provided that environmental variables that influence bioremediation effectiveness are maintained at optimum levels. This study delves further into the two main bioremediation methods, their principles, benefits, drawbacks, and future possibilities [9].

Guzik U et al. discussed Natural carriers in Bioremediation in which they explained how Currently, the cheapest and least harmful method of removing xenobiotics from the environment is ioremediation of contaminated groundwater or soil. Immobilization of microorganisms capable of digesting particular pollutants speeds up bioremediation procedures, lowers costs, and allows for various biocatalyst applications. Because of its simplicity and lack of toxicity, adsorption on the surface is the most often used technique in bioremediation among the established ways of immobilization. For effective bioremediation, the carrier of choice is critical. In addition, the kind of procedure (in situ or ex situ), the type of pollution, and the characteristics of immobilized microbes must all be considered. For these reasons, the article summarizes recent scientific reports on the use of natural carriers in bioremediation, including efficiency, carrier impact on microorganisms and contamination, and research methodology [10].

3. DISCUSSION

A short history of bioremediation technology development is given. The main features and limits are discussed, as well as a sketch of the current state of the art in field applications. The word "bioremediation" was used to describe the process of removing hazardous waste from the environment using biological agents. The most successful management technique for managing polluted environments and recovering contaminated soil is bioremediation. Bioremediation, both in situ and ex-situ, has seen a surge in scientific interest, thanks in part to the increasing usage of natural attenuation, which is mostly due to biodegradation. Emerging contamination issues are also being addressed via bioremediation and natural attention. Microbes are very useful in cleaning up a polluted environment. The bioremediation process involves a variety of microorganisms, including aerobes, anaerobes, and fungi. Biodegradation is a highly profitable and appealing alternative for remediating, cleaning, controlling, and recovering contaminated environments via microbial activity. The rate at which undesirable waste compounds degrade is governed by competition with biological agents, insufficient food supply, unpleasant external abiotic conditions (aeration, moisture, pH, temperature), and poor pollutant bioavailability. Because of these variables, biodegradation under natural conditions is less effective, resulting in less desirable results. Because bioremediation is only successful when the environment allows for microbial growth and activity.

4. CONCLUSION

Bioremediation has been utilized in a variety of locations throughout the world with various degrees of effectiveness. Bioremediation is a method of removing pollutants by accelerating natural biodegradation processes. So, by improving our understanding of microbial communities and their responses to the natural environment and pollutants, expanding our knowledge of microbe genetics to improve their ability to degrade pollutants, conducting field trials of new cost-effective bioremediation techniques, and dedicating sites for long-term research, we can improve our ability to degrade pollutants. There's no denying that bioremediation is helping to pave the road to greener pastures. Regardless of whatever element of bioremediation is utilized, this technique provides a quick and inexpensive solution to remediate polluted ground water and soil. The benefits outweigh the drawbacks in most cases, as shown by the growing number of sites that utilize this technology and its rising popularity over time. Generally, different species are investigated from various locations and shown to be efficient control mechanisms.

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