BIOREMEDIATION

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ABSTRACT

Nowadays the globe environment facing a highly critical situation due to the growing cities, industries and increasing population in the limited natural resource. The growth of population reflects the drastic changes in the environment. There is a use of highly developed environmental management system and biotechnological technology to remove the contaminants from natural resource is known as bioremediation. Bioremediation is one of the most considered and useful alternative method for eradicate the contaminated from the natural for sustainable waste management. Today's recent advancement of technologies, multiplies the bioremediation process for production of the natural resource from recycling waste material. This chapter covers the detail notes about bioremediation and their principles in working process and the types of methods involved in contaminated based areas and the role of microbes in remediation process and their applications.

Keywords : Bioremediation, contamination, microbes, methods, applications.

I. INTRODUCTION

Over the years, human activities have led to the release of hazardous substances into the soil, water, and air, resulting in widespread environmental degradation. bioremediation is a promising and eco-friendly approach to tackle various pollution problems. Bioremediation, derived from "bio" (life) and "remediation" (restoration), is a cutting-edge and sustainable technique that utilizes the remarkable abilities of living organisms to naturally clean up and mitigate pollution in our environment. The fundamental principle behind bioremediation lies in the metabolic potential of these living organisms, which can break down complex contaminants into simpler and less harmful compounds through natural biochemical processes. This not only helps in restoring the contaminated environment but also promotes a self-sustaining cycle that fosters ecological balance. Bioremediation comes in various forms, including biodegradation, phytoremediation, and bioaugmentation. Each method targets specific types of pollutants and environmental conditions. As research and technological advancements continue to enhance our understanding of bioremediation processes, its applications are becoming more widespread. From cleaning up oil spills to remediating industrial waste sites and even managing pollutants in urban areas, bioremediation is reshaping the way we approach environmental conservation.

Various physicochemical techniques have been widely used for the removal of pollutants from the environment, but these techniques are often not practical, due to factors such as high maintenance and

operational costs, and the production of secondary contaminants that have a high toxicity. One promising technique for removing pollutants is known as biological remediation, with advantages over other methods in terms of removal efficiency, eco-friendly process, and low operational and maintenance cost. The bioremediation process utilizes microorganisms such as fungi and bacteria to remove or modify pollutants. Microalgal technology has also shown to be a promising approach in dealing with pollutants in a sustainable manner. The microalgae application has other benefits due to its production growth rate which can be faster in wastewater than freshwater and simultaneously produces valuable products like biofuel, pigments, nutraceuticals, aquatic feedstock from biomass generated.

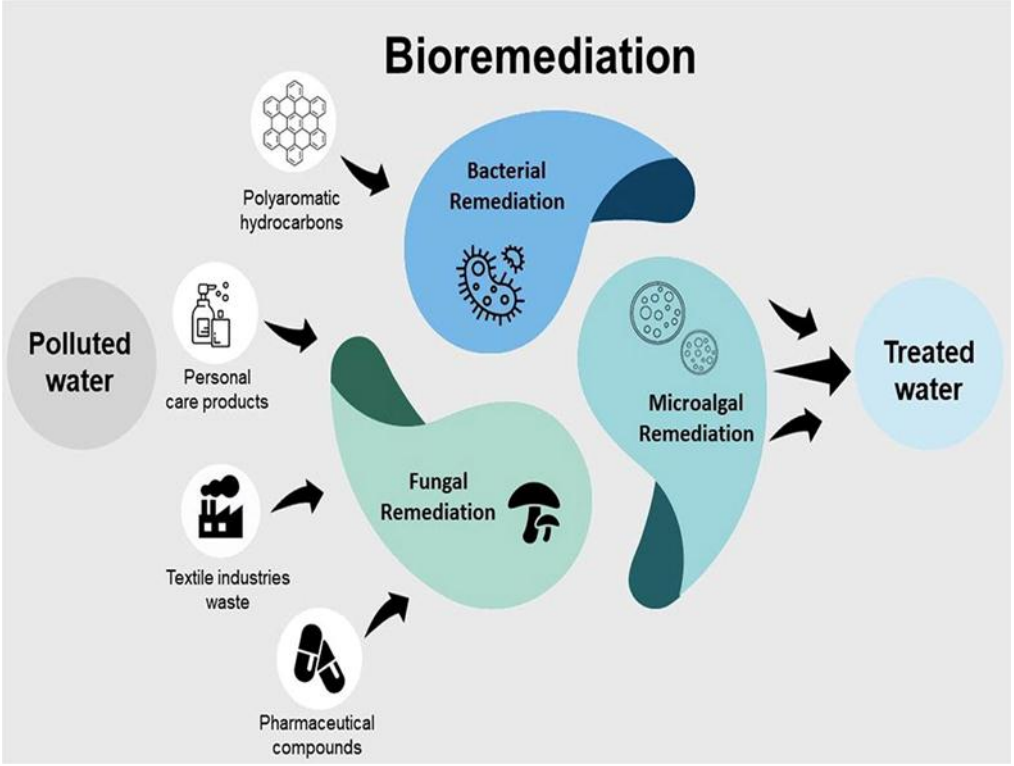

Fig 1:Bioremeditaion

II. CATEGORIES OF BIOREMEDIATION

Biological remediation can be categorized into two types

- Microbial remediation
- Phytoremediation

A. Microbial Remediation

Micro-organisms are well known for their ability to break down a huge range of organic compounds and absorb inorganic substances. Currently, microbes are used to clean up pollution treatment in processes known as bioremediation. Different microbial systems like bacteria, fungi, yeasts, and actinomycetes can be used for removal of toxic and other contaminants from the environment. Microorganisms are readily available, rapidly characterized, highly diverse, omnipresent, and can use many noxious elements as their nutrient source. They can be applied in both in situ and ex-situ conditions. The bacteria that can degrade major pollutants

include *Pseudomonas, Aeromonas, Moraxella, Beijerinckia, Flavobacteria, chrobacteria, Nocardia, Corynebacteria, Acinetobacter, Mycobactena, Modococci, Streptomyces, Bacili, Arthrobacter, Aeromonas, and Cyanobacteria.*

B. Phytoremediation

Phytoremediation is a bioremediation process that uses various types of plants to remove, transfer, stabilize, and or destroy contaminants in the soil and groundwater. There are different types of phytoremediation mechanisms. (fig.2) They are

- Rhizosphere biodegradation
- Phyto-stabilization
- Phyto-accumulation (also called phytoextraction)
- Hydroponic Systems for Treating Water Streams (Rhizofiltration).
- Phyto-volatilization
- Phyto-degradation
- Hydraulic Control

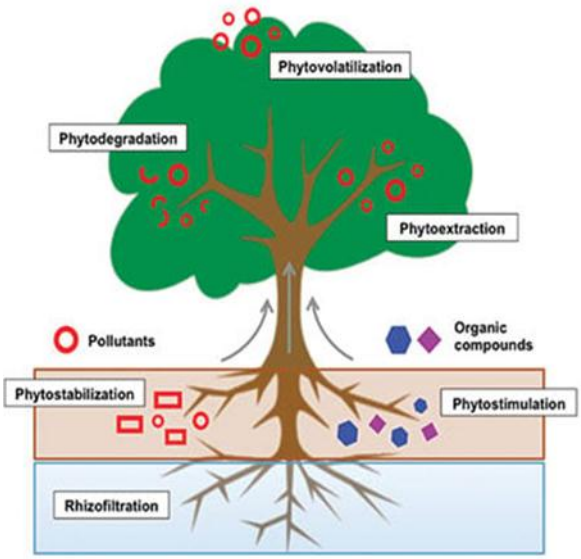

Fig 2.Phytoremeditaion

III. METHODS OF BIOREMEDIATION

Bioremediation techniques encompass a variety of approaches that utilize living organisms to clean up contaminated environments. Each technique is tailored to the specific type of pollutant, the nature of the contaminated site, and the desired remediation outcomes. There are different methods of bioremediation

- Natural attenuation or intrinsic bioremediation
- Biostimulation

Technologies can be generally classified as in situ or ex-situ. Bioremediation (fig.3)

- In Situ bioremediation

- Ex Situ bioremediation

A.Natural attenuation or intrinsic bioremediation or Bio-attenuation

Bioremediation occurs on its own without adding anything (fig 7).

B. Biostimulation

Bioremediation is spurred on via the addition of fertilizers to increase the bioavailability within the medium. (fig. 4).

C. In Situ Bioremediation

In Situ Bioremediation is a bioremediation technique that involves treating the contaminated material at the site without removing it. This approach utilizes naturally occurring or introduced microorganisms to degrade, transform, or remove pollutants in their original location. In Situ bioremediation is particularly applicable to contaminated soil and ground water, as well as some surface water and sediment environments.

D. Ex Situ Bioremeditaion

Ex situ bioremediation is a type of environmental remediation technique used to clean up contaminated sites by removing the pollutants and treating them outside of their original location. Unlike in situ bioremediation, where the cleanup process occurs in the same place as the contamination, ex situ bioremediation involves excavating or
removing contaminated materials and treating them elsewhere.

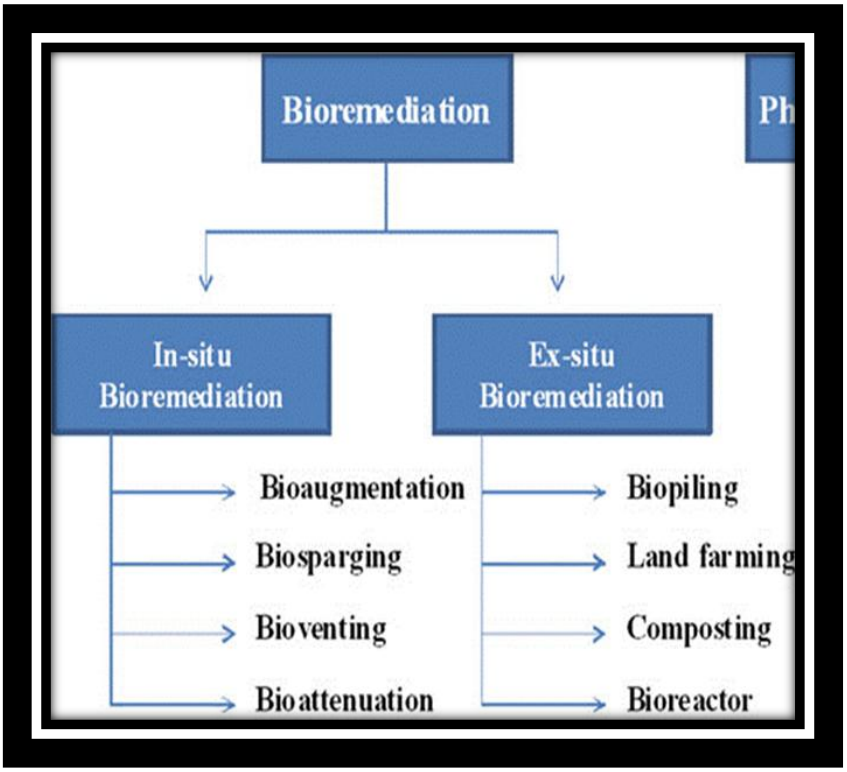

Fig 3. Methods of bioremediation

C)In Situ bioremediation

Bioaugmentation:

Bioaugmentation involves introducing specific strains of microorganisms (bacteria, fungi, or other microbes) to the contaminated site to enhance the natural degradation of pollutants. These introduced organisms may be more efficient at breaking down the particular contaminants present (fig 4).

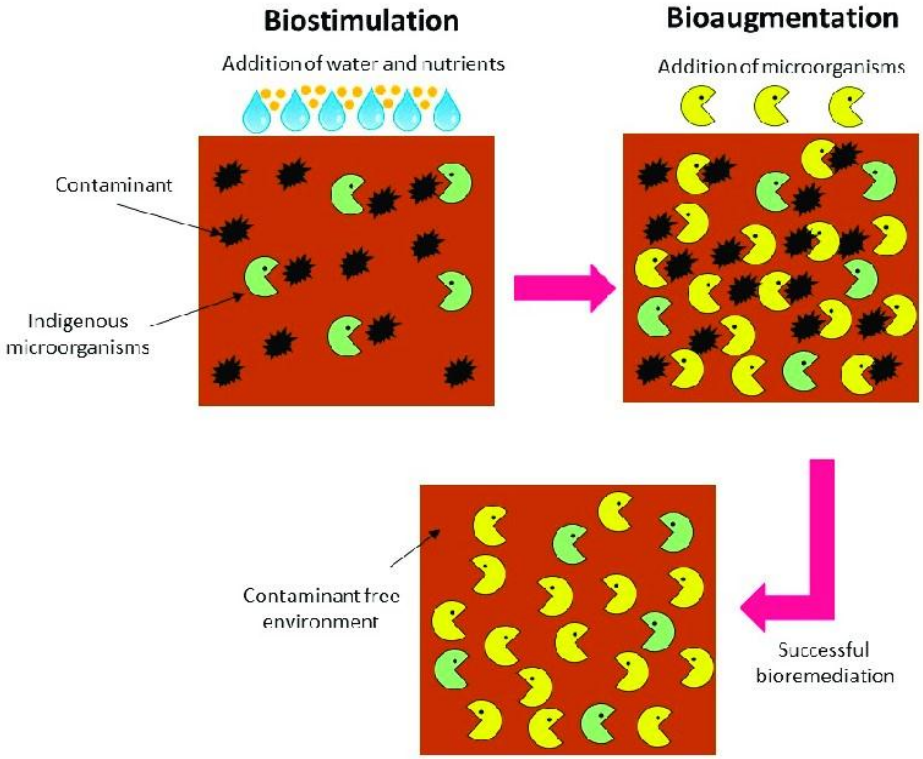

Fig 4 Biostumulation and bioaugmentation

Bioventing

Bioventing is a technique used to treat soil contaminated with volatile organic compounds (VOCs). Air and oxygen are pumped into the soil to enhance the activity of aerobic microorganisms that can metabolize the contaminants (fig 5).

Biosparging:

Similar to bioventing, biosparging is used to remediate groundwater contaminated with VOCs. Air or oxygen is injected into the saturated zone to promote microbial degradation of the pollutants (fig 6).

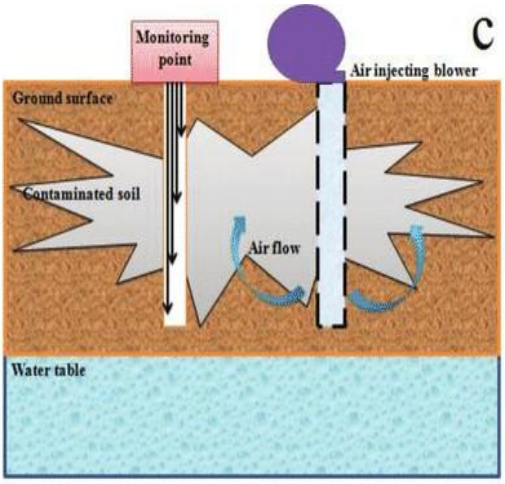

Fig 5.Bioventing

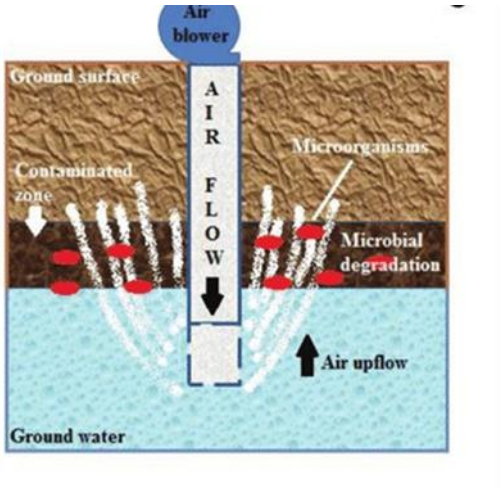

Fig 6.Biosparging

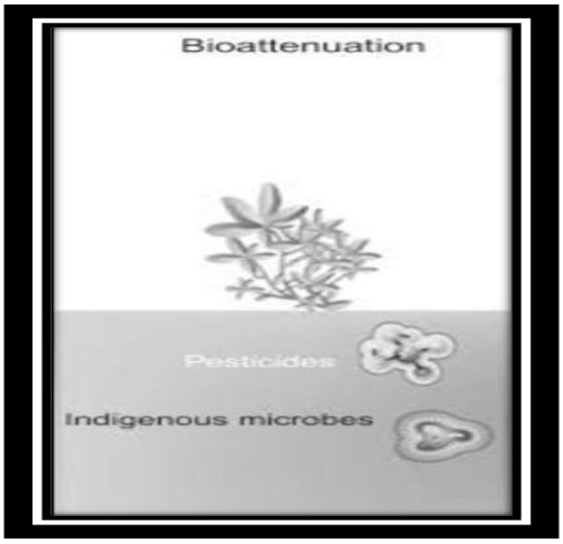

Fig.7 Bioattenuation

D) Ex Situ Bioremediation

Biopiling:

Biopiling involve the containment of contaminated soil in a specially constructed treatment area. The soil is then actively managed and mixed to create favorable conditions for microbial degradation. This method often includes aeration, moisture control, and nutrient addition to enhance microbial activity (fig 8).

Landfarming:

In landfarming, contaminated soil is spread out over a prepared area and periodically tilled to mix in oxygen and promote microbial degradation of the pollutants. Nutrients may also be added to enhance microbial activity. This method is suitable for treating petroleum hydrocarbon-contaminated soils. (fig 9).

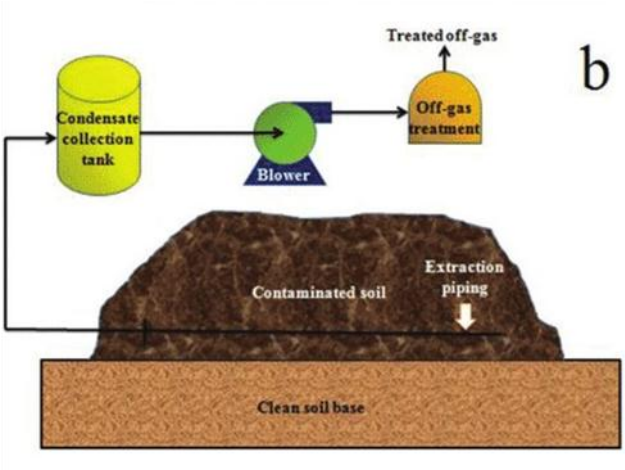

Fig.8 Biopiling

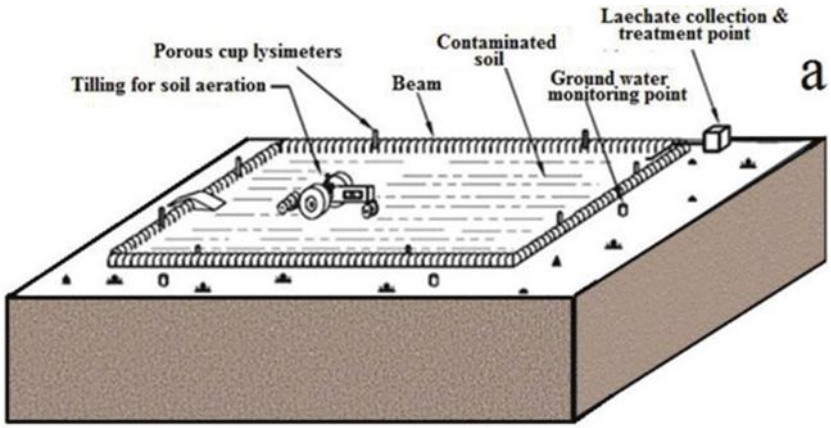

Fig.9 Landfarming

Composting:

Composting is a form of ex situ bioremediation mainly used for organic contaminants. The contaminated material, such as soil or organic waste, is mixed with bulking agents like wood chips or

yard waste to create compost. During the composting process, naturally occurring microorganisms break down the contaminants (fig 10).

Fig.10 composting

Bioreactors:

Bioreactors are enclosed containers where contaminated materials, such as soil or water, are treated with specific strains of microorganisms. The environmental conditions within the bioreactor are carefully controlled to optimize biodegradation (fig 11)

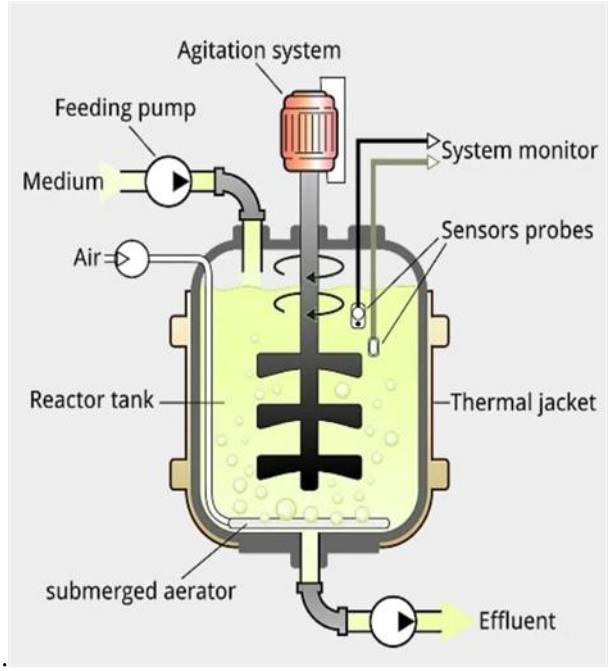

Fig.11 Bioreactor

IV. APPLICATIONS OF BIOREMEDIATION

Bioremediation has been widely applied in various environmental cleanup scenarios due to its cost-effectiveness, sustainability, and ability to harness natural biological processes. Some of the key applications of bioremediation include

Oil Spill Cleanup:

Bioremediation has been successfully used to clean up oil spills in marine and terrestrial environments. Microorganisms, such as certain bacteria and fungi, are employed to break down the hydrocarbons present in the spilled oil, effectively reducing its impact on ecosystems.

Contaminated Soil Remediation:

Bioremediation is applied to treat soils contaminated with various pollutants, including petroleum hydrocarbons, solvents, pesticides, and heavy metals. Microorganisms in the soil naturally degrade these contaminants when provided with appropriate conditions and nutrients.

Groundwater Cleanup:

In cases where groundwater is contaminated, bioremediation techniques can be employed to stimulate the growth of indigenous microorganisms that can degrade the pollutants in place or pump the groundwater to an ex situ treatment system.

Wastewater Treatment:

Bioremediation is used in wastewater treatment plants to remove organic pollutants from industrial and municipal wastewater. Microorganisms in activated sludge systems break down organic matter, reducing its environmental impact before the treated water is discharged.

Landfill Remediation:

Bioremediation is applied to treat waste materials in landfills, particularly the degradation of organic wastes. This can reduce the production of harmful landfill gases and the leaching of pollutants into the surrounding soil and groundwater. Published in Archives of Petroleum & Environmental Biotechnology 2019.

Mining Site Cleanup:

Abandoned mining sites often contain elevated levels of heavy metals and other toxic compounds. Bioremediation, particularly using plants or microorganisms, can help stabilize or remove these contaminants from the soil and water.

Biodegradable Waste Management:

Bioremediation processes can be employed to treat biodegradable organic waste, such as food waste, agricultural residues, and yard waste, in composting facilities, reducing the environmental burden of waste disposal.

Brownfield Redevelopment:

Bioremediation is utilized in redeveloping brownfield sites, where past industrial activities have left contaminants in the soil and groundwater. By cleaning up the contamination, these sites can be repurposed for new developments.

Bioremediation of Contaminated Water Bodies:

Polluted water bodies, such as rivers, lakes, and ponds, can be treated using bioremediation techniques. Floating treatment wetlands and other systems can harness the abilities of plants and microorganisms to remove pollutants from the water.

Some example of micro organisms that involved in bioremediations process in different type of pollutens in the environment. (Table.1).

Table.1 microorganisms and their applications in different contaminant site

Microorganisms	Applications
Pseudomonas aeruginosa	Bioremediation of oil contaminated soil
Bacillus subtilis	Bioremediation of hydrocarbon contaminated site
Nocandiopsis incentsis	Bioremediation of marine environment
Pseudomonas cepacia	Bioremediation of marine environment
Micrococcus inteus	Bioremediation of oil contaminated environment

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