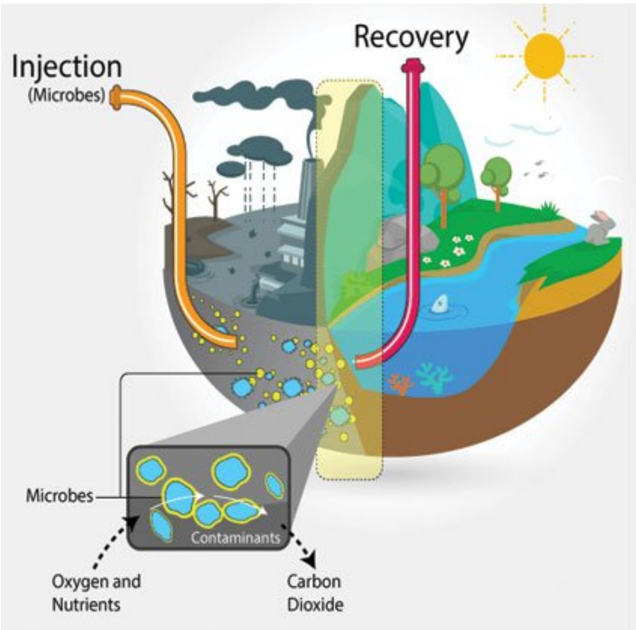
CULTURE BASED APPROACHES OF Bioremediation

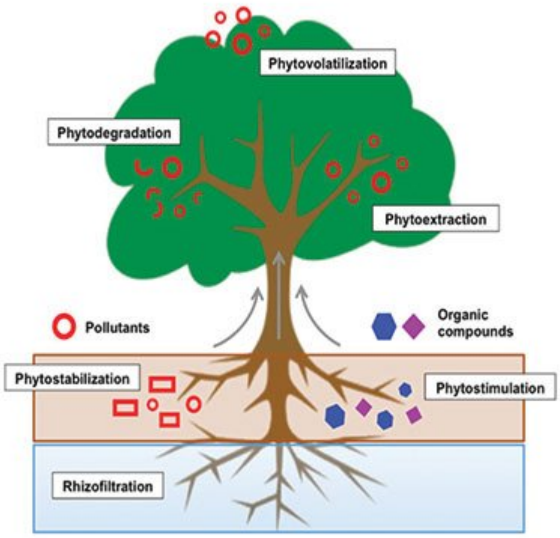
Table of Contents

Bioremediation refers to the use of either naturally occurring or deliberately introduced microorganisms to consume and break down environmental pollutants, in order to clean a polluted site.

- It is a process that uses mainly microorganisms but also plants, or microbial or plant enzymes to detoxify contaminants in the soil and other environments.
- The concept includes biodegradation, which refers to the partial and sometimes total, transformation or detoxification of contaminants by microorganisms and plants.

- The process of bioremediation enhances the rate of the natural microbial degradation of contaminants by supplementing the indigenous microorganisms (bacteria or fungi) with nutrients, carbon sources, or electron donors (biostimulation, biorestoration) or by adding an enriched culture of microorganisms that have specific characteristics that allow them to degrade the desired contaminant at a quicker rate (bioaugmentation).





Objective of Bioremediation

- The goal of bioremediation is to at least reduce pollutant levels to undetectable, nontoxic, or acceptable levels, that is, to within limits set by regulatory agencies or, ideally, to completely mineralize organopollutants to carbon dioxide.

Principle of Bioremediation

- Bioremediation relies on stimulating the growth of certain microbes that use contaminants like oil, solvents, and pesticides as a source of food and energy.
- These microbes consume the contaminants, converting them into small amounts of water and harmless gases like carbon dioxide.
- Effective bioremediation needs a combination of the right temperature, nutrients, and food; otherwise, it may take much longer for the cleanup of contaminants.
- If conditions are not favorable for bioremediation, they can be improved by adding "amendments" to the environment, such as molasses, vegetable oil or simply air.
- These amendments create optimum conditions for microbes to flourish and complete the bioremediation process.
- The process of bioremediation can take anywhere from a few months to several years.
- The amount of time required depends on variables such as the size of the contaminated area, the concentration of contaminants, conditions such as temperature and soil density, and whether bioremediation will take place in situ or ex-situ.

Categories of Bioremediation

Biological remediation can be categorized into two types: microbial remediation and phytoremediation.

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; in addition, many extreme environmental conditions can be cleaned by such entities.
- Although many microorganisms are capable of degrading crude oil present in soil, it has been found beneficial to employ a mix culture approach than the pure cultures in bioremediation as it shows the synergistic interactions.
- Different bacteria can be used for the removal of petroleum hydrocarbon contaminants from soil.
- The bacteria that can degrade major pollutants include *Pseudomonas, Aeromonas, Moraxella, Beijerinckia, Flavobacteria,* chro

bacteria, *Nocardia, Corynebacteria,* Acinetobacter, Mycobactena, *Modococci, St reptomyces,* Bacili, *Arthrobacter, Aeromonas,* and *Cyanobacteria*.

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 several different types of phytoremediation mechanisms.

1. **Rhizosphere biodegradation.** In this process, the plant releases natural substances through its roots, supplying nutrients to microorganisms in the soil. The microorganisms enhance biological degradation.
2. **Phyto-stabilization.**In this process, chemical compounds produced by the plant immobilize contaminants, rather than degrade them.
3. **Phyto-accumulation** (also called phytoextraction). In this process, plant roots absorb the contaminants along with other nutrients and water. The contaminant mass is not destroyed but ends up in the plant shoots and leaves. This method is used primarily for wastes containing metals.
4. **Hydroponic Systems for Treating Water Streams (Rhizofiltration)**. Rhizofiltration is similar to phytoaccumulation, but the plants used for cleanup are raised in greenhouses with their roots in water. This method of growing can be used for ex-situ groundwater treatment. That is, groundwater is pumped to the

surface to irrigate these plants. Typically hydroponic systems utilize an artificial soil medium, such as sand mixed with perlite or vermiculite. As the roots become saturated with contaminants, they are harvested and disposed of.

5. **Phyto-volatilization.** In this process, plants take up water containing organic contaminants and release the contaminants into the air through their leaves.
6. **Phyto-degradation.** In this process, plants actually metabolize and destroy contaminants within plant tissues.
7. **Hydraulic Control.** In this process, trees indirectly remediate by controlling the groundwater movement. Trees act as natural pumps when their roots reach down towards the water table and establish a dense root mass that takes up large quantities of water. A poplar tree, for example, pulls out of the ground 30 gallons of water per day, and cottonwood can absorb up to 350 gallons per day.

Types of Bioremediation Methods

- **Natural attenuation or intrinsic bioremediation:** Bioremediation occurs on its own without adding anything.
- **Biostimulation:** Bioremediation is spurred on via the addition of fertilizers to increase the bioavailability within the medium.

Technologies can be generally classified as in situ or ex-situ.

- **In situ bioremediation**: It involves treating the contaminated material at the site.

- **Ex situ bioremediation:** It involves the removal of the contaminated material to be treated elsewhere.

Methods of Bioremediation

Some examples of bioremediation-related technologies are:

1. Phytoremediation
2. Bioventing
3. Bioleaching
4. Land-farming
5. Bioreactor
6. Composting
7. Bioaugmentation
8. Rhizo-filtration
9. Biostimulation

Applications of Bioremediation

- Bioremediation is used for the remediation of metals, radionuclides, pesticides, explosives, fuels, volatile organic compounds (VOCs) and semi-volatile organic compounds (SVOCs).
- Research is underway to understand the role of phytoremediation to remediate perchlorate, a contaminant that has been shown to be persistent in surface and groundwater systems.

- It may be used to clean up contaminants found in soil and groundwater.
- For radioactive substances, chelating agents are sometimes used to make the contaminants amenable to plant uptake.

Advantages of Bioremediation

Bioremediation has a number of advantages over other cleanup methods.

- As it only uses natural processes, it is a relatively green method that causes less damage to ecosystems.
- It often takes place underground, as amendments and microbes can be pumped underground to clean up contaminants in groundwater and soil; therefore, it does not cause much disruption to nearby communities.
- The process of bioremediation creates few harmful byproducts since contaminants and pollutants are converted into water and harmless gases like carbon dioxide.
- Bioremediations is cheaper than most cleanup methods, as it does not require a great deal of equipment or labor.
- Bioremediation can be tailored to the needs of the polluted site in question and the specific microbes needed to break down the pollutant are encouraged by selecting the limiting factor needed to promote their growth.

Limitations and Concerns of Bioremediation

- The toxicity and bioavailability of biodegradation products are not always known.
- Degradation by-products may be mobilized in groundwater or bio-accumulated in animals.
- Additional research is needed to determine the fate of various compounds in the plant metabolic cycle to ensure that plant droppings and products do not contribute to toxic or harmful chemicals into the food chain.
- Scientists need to establish whether contaminants that collect in the leaves and wood of trees are released when the leaves fall in the autumn or when firewood or mulch from the trees is used.
- Disposal of harvested plants can be a problem if they contain high levels of heavy metals.
- The depth of the contaminants limits treatment. In most cases, it is limited to shallow soils, streams, and groundwater.
- Generally, the use of phytoremediation is limited to sites with lower contaminant concentrations and contamination in shallow soils, streams, and groundwater.
- The success of phytoremediation may be seasonal, depending on location. Other climatic factors will also influence its effectiveness.

- The success of remediation depends on establishing a selected plant community. Introducing new plant species can have widespread ecological ramifications. It should be studied beforehand and monitored
- If contaminant concentrations are too high, plants may die.
- Some phytoremediation transfers contamination across media, (e.g., from soil to air).
- Phytoremediation is not effective for strongly sorbed contaminants such as polychlorinated biphenyls (PCBs).
- Phytoremediation requires a large surface area of land for remediation.