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1. Bioremediation: A Green Approach for the Sustainable Environment Management

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1.1 Introduction:

The quality of life on Earth is linked inextricably to the overall quality of the environment. In early times, we believed that we had an unlimited abundance of land and resources; today, however, the resources in the world show, in greater or lesser degree, our carelessness and negligence in using them. The problems associated with contaminated sites now assume increasing prominence in many countries. Contaminated lands generally result from past industrial activities when awareness of the health and environmental effects connected with the production, use, and disposal of hazardous substance number of contaminated sites is significant [1]. It is now widely recognized that contaminated land is a potential threat to human health, and its continual discovery over recent years has led to international efforts to remedy many of these sites, either as a response to the risk of adverse health or environmental effects caused by contamination or to enable the site to be redeveloped for use. Bio-remediation is a treatment process that uses naturally occurring microorganism (yeast fungi, bacteria) to breakdown or degrade hazardous substance into less toxic or nontoxic substance.

The microorganisms breakdown the organic contaminants into harmless product mainly CO_2 and water.

Microorganism Microorganism

Organic contaminants → $Co_2 + H_20$

Once the contaminant or degrade the microorganism population is reduced because they have used all their food source.

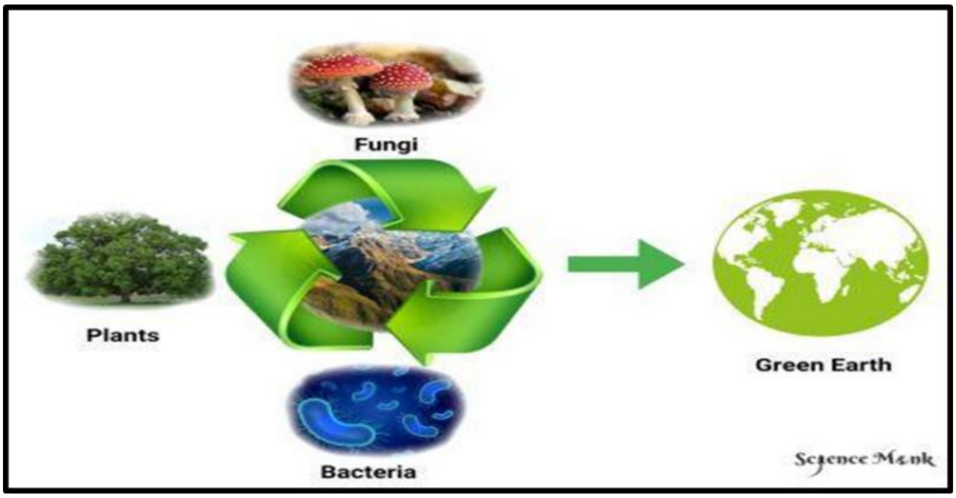
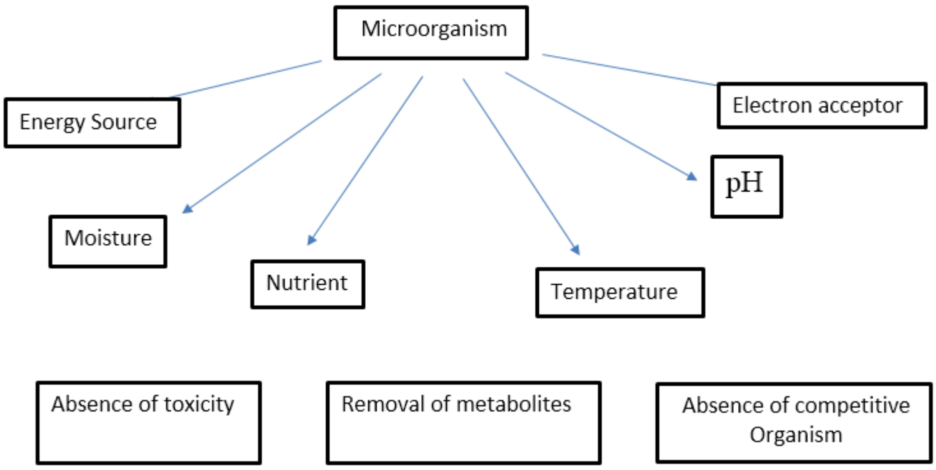


Figure 1.1: Microorganism

1.1.1 Requirements for Biodegradation:



1.2 Principles of Bioremediation:

Environmental biotechnology is not a new field; composting and wastewater treatments are familiar examples of old environmental biotechnologies. However, recent studies in molecular biology and ecology offer opportunities for more efficient biological processes. Notable accomplishments of these studies include the clean-up of polluted water and land areas. Bioremediation is defined as the process whereby organic wastes are biologically degraded under controlled conditions to an innocuous state, or to levels below concentration limits established by regulatory authorities.

By definition, bioremediation is the use of living organisms, primarily microorganisms, to degrade the environmental contaminants into less toxic forms. It uses naturally occurring bacteria and fungi or plants to degrade or detoxify substances hazardous to human health and/or the environment. The microorganisms may be indigenous to a contaminated area or they may be isolated from elsewhere and brought to the contaminated site. Contaminant compounds are transformed by living organisms through reactions that take place as a part of their metabolic processes. Biodegradation of a compound is often a result of the actions of multiple organisms.

When microorganisms are imported to a contaminated site to enhance degradation we have a process known as bio augmentation. For bioremediation to be effective, microorganisms must enzymatically attack the pollutants and convert them to harmless products. As bioremediation can be effective only where environmental conditions permit microbial growth and activity, its application often involves the manipulation of environmental parameters to allow microbial growth and degradation to proceed at a faster rate.

Like other technologies, bioremediation has its limitations. Some contaminants, such as chlorinated organic or high aromatic hydrocarbons, are resistant to microbial attack. They are degraded either slowly or not at all, hence it is not easy to predict the rates of clean-up for a bioremediation exercise; there are no rules to predict if a contaminant can be degraded. Bioremediation techniques are typically more economical than traditional methods such as incineration, and some pollutants can be treated on site, thus reducing exposure risks for clean-up personnel, or potentially wider exposure as a result of transportation accidents.

Since bioremediation is based on natural attenuation the public considers it more acceptable than other technologies. Most bioremediation systems are run under aerobic conditions, but running a system under anaerobic conditions may permit microbial organisms to degrade otherwise recalcitrant molecules.

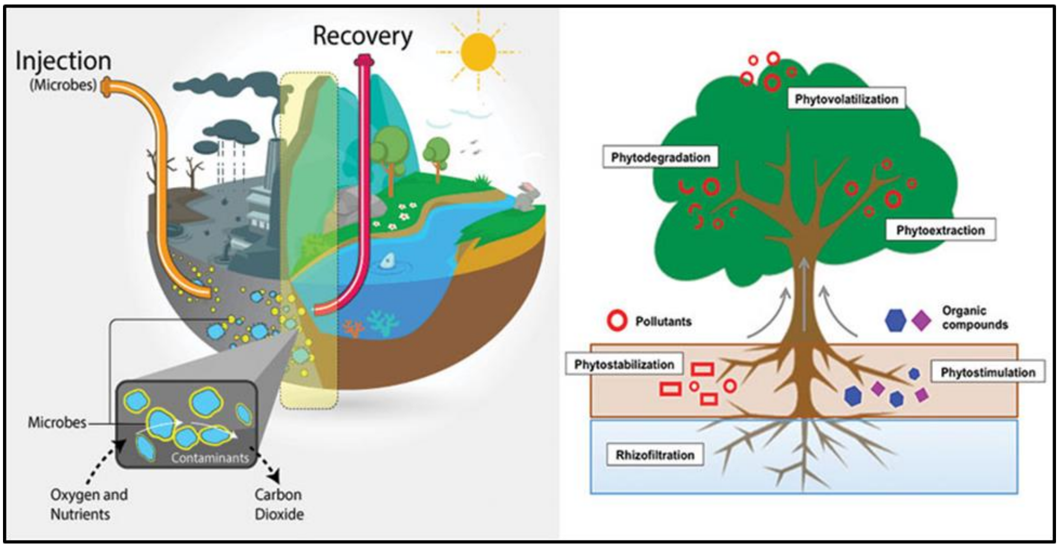


Figure 1.2: Bioremediation

1.3 Factor Effecting Bioremediation:

A number of environmental factor influencing the by remediation rate these factors are:

A. Hydrogen ion concentration (pH):

Bacteria exhibit their growth opinion at or near the nutral pH.

Acidophilus bacteria show optimum at acidic PH and alkali bacteria are so optimum growth on alkaline pH, the process of control soil and water pH please call liming which include the addition of Ca $(OH)_2$, $Caco_3$ etc.

Increase soil pH decrease the availability of Ca, Mg, Na, k etc. Where decrease in pH decreases the nitrates and chlorides.

B. Temperature:

Temperature affect the metabolism of growth rate and soil matrix physical and chemical condition of soil.

Mesophilic bacteria are most important because they are casily cultivated and relatively short doubling time in composting or subsurface treatment thermophilic bacteria are more useful.

C. Water content:

Every living being required water for their survival so, no Organism can grow in the absence of water as it is the important part of microbial growth. Water are required for solubilization of pollutants and process many other metabolites activity.

D. Nutrient availability:

Nutrient are generally supplemented in all kinds of remediation process such as soil sediment groundwater and surface water nutrient requirement depends on the nature of the contaminants.

E. External electron availability:

In case of aerobic remediation oxygen is used as the aerobic electron acceptor where as various aliphatic and aromatic are carried out by nitrifying bacteria, sulfate, Iron, molybdenum bacteria and by methanogens.

F. Gene Expression:

The availability of indigenous microorganism to degrade organic pollutants is dependent on the expression of the gene encoding the required enzyme.

G. Co-metabolism:

Co-metabolism is a process whereby microbes involved in the metabolism of growth promoting substrate also transform other organic contaminants which can be called as Co-substrate but these are not growth supporting, it provided as the only source of carbon and energy.

1.4 Indigenous Microorganism:

Indigenous microorganism are those microorganism that are found already liming at a given site. To stimulate the growth of this indigenous microorganism the proper soil temperature, oxygen and nutrient content may need to provide.

1.5 Types of Bio-remediation:

The bioremediation mainly two types

1. In-Situ Bioremediation.
2. Ex-Situ Bioremediation.

1.5.1 In-Situ Bioremediation:

In-Situ bioremediation is when the contaminated site is cleaned up exactly where it occurred. It is most commonly used type of bioremediation because it is the cheapest and most efficient so it's generally better to use.

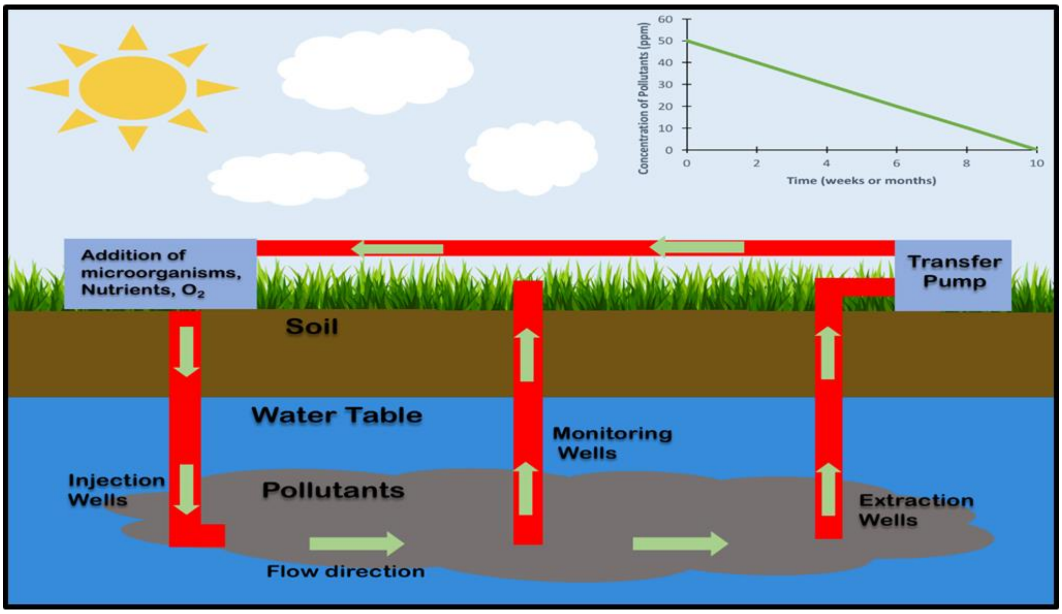


Figure 1.3: In-Situ Bioremediation

There are two main types of In-situ bioremediation

- Intrinsic bioremediation.
- Accelerated bioremediation or engineered bioremediation.

A. Intrinsic Bioremediation:

Intrinsic by remediation uses microorganism already present in the environment to biodegrade harmful contaminant.

- There is no human interaction involves in this type of bioremediation.
- It is cheapest and most commonly used method.
- This process does not increase the rate of degradation.

Advantage of In Situ Bioremediation:

- Sites of bioremediation remain minimally disrupted.
- This process is cost effective with minimal exposure to public or site personnel.

Disadvantages of In-Situ Bioremediation:

- The Microbes use in this case, degrading ability varies seasonally.
- It is a very time consuming process.

B. Accelerated Bioremediation:

In accelerated by remediation either substrate on nutrients are added to the environment to help breakdown the toxic spill by making the environment grow more rapidly.

Microorganism are indigenous baat occasionally microorganism that are very efficient at degrading a certain contaminant are additionally added.

The important features of accelerated by mediation are

- Hydraulic conductivity.
- Filtration.
- Contaminant of the system.

It mainly three types

- Bioventing.
- Water Circulating System.
- Air Sparging.

- **Bioventing:**

Bioventing is the most common in situ treatment and involve supplying air and nutrients through Wells to contaminated soil to stimulate the indigenous bacteria.

In this technique air is poured from the contaminated area by vacuum creates a negative air pressure which ensures flora from out Internet through biologically active zone. The amount of pressure and vacuum point depends on the size of contaminated area.

If stimulants are required can be supplied by water solution.

N2 may be added to increase the growth of microorganism.

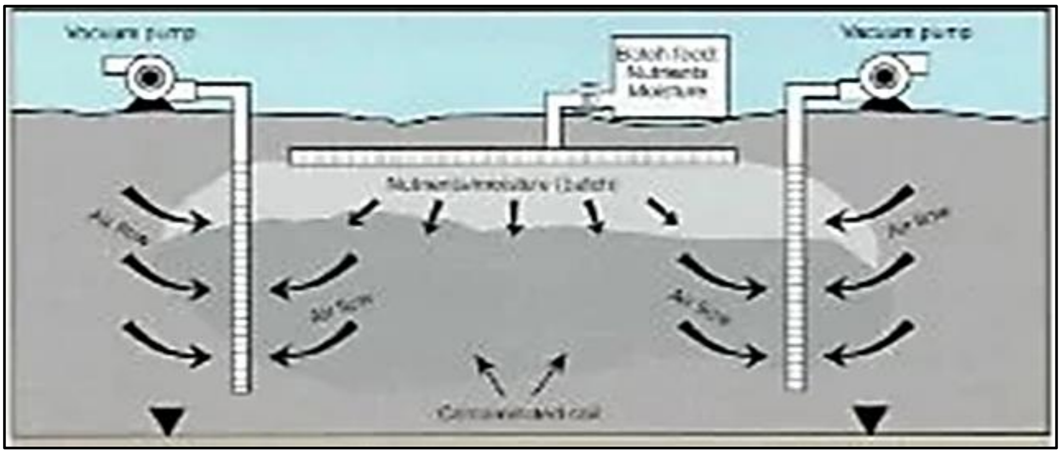


Figure 1.4: Bioventing

- **Injection of H_2O_2:**

The process of oxygen to stimulate the activity of naturally occurring microorganism by circulating hydrogen peroxide through contaminated soil to spread the bioremediation of organic contaminants.

The oxygen supply done with water either air saturated or in the form of H_2o_2 one problem in this technique is clogging. This is avoid by periodic use of disinfectant like cl- and H_2o_2.

- **Bio-Sparging:**

a. Air water and nutrient directly earlier to the contaminated site.
b. It is the most effective way to wrap it bio degradation.
c. Compressed air is pressed below contaminated area.
d. It helps to transfer the contaminants saturated to unsaturated zone.
e. It increase the contact between soil and ground water.

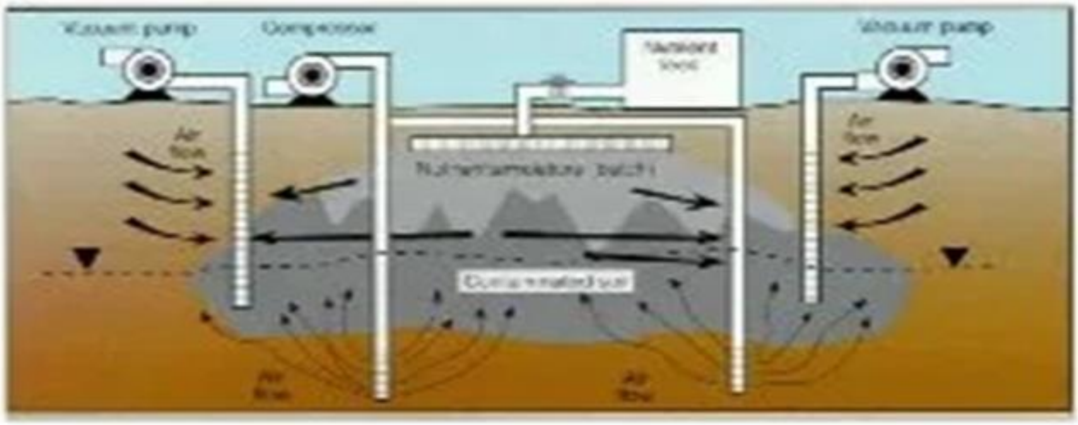


Figure 1.5: Bio-Sparging

- **Bio-Augmentation:**

Bio-remediation frequently involves the microorganism indigenous or exogenous to the contaminated site.

- **Bio-Magnification:**

The phenomenon of progressive increase in the concentration of a xenobiotics compound as the substance is passed through the food chain is referred to as bio magnification.

Advantage Oh In-Situ Bioremediation:

a. Cost effective with minimal expensive to public or site personnel.
b. Site of bioremediation remain minimally disrupted.
c. Many hazardous transformed to the harmless product.
d. Very time consuming process.
e. Sites are directly exposed to environmental factors.
f. Microbial degrading ability various seasonally.

1.5.2 Ex-Sito Bioremediation:

When the contaminated land are taken out of the area to be cleaned up by the Organism is called Ex-Situ bioremediation.

This type of bioremediation is generally used only when the site is treated for some reason usually by the spill that needs to be cleaned up.

It is very expensive and to the area. It is applicable for small contamination site.

Figure 1.6: Ex-Sito Bio Remediation

A. Land Farming:

Land farming is a simple technique in which contaminated soil is excavated and spread over a prepared bed and periodically tilled until pollutants are degraded. The goal is to stimulate indigenous bio degradative microorganisms and facilitate their aerobic degradation of contaminants. In general, the practice is limited to the treatment of superficial 10–35 cm of soil. Since land farming has the potential to reduce monitoring and maintenance costs, as well as clean-up liabilities, it has received much attention as a disposal alternative.

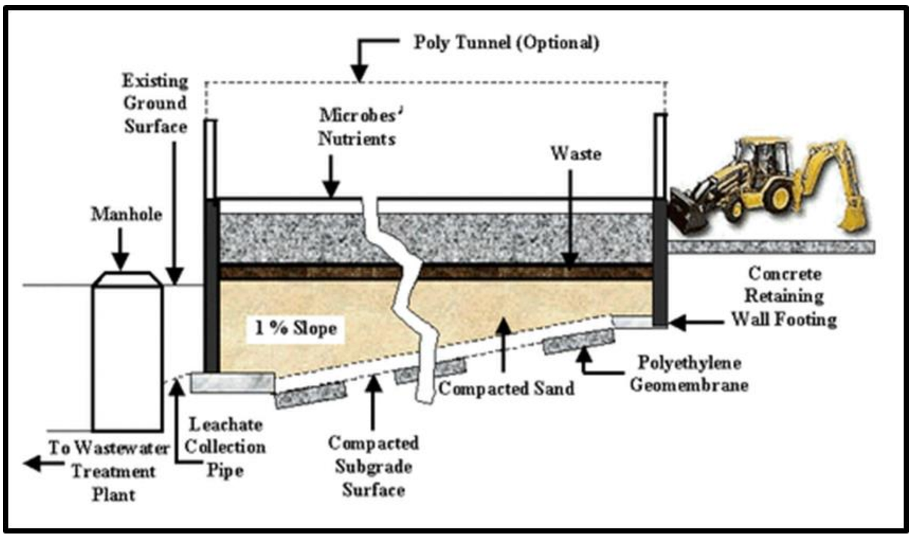


Figure 1.7: Land Farming

B. Composting:

Composting is a technique that involves combining contaminated soil with nonhazardous organic amendants such as manure or agricultural wastes. The presence of these organic materials supports the development of a rich microbial population and elevated temperature characteristic of composting. Bio piles are a hybrid of land farming and composting. Essentially, engineered cells are constructed as aerated composted piles. Typically used for treatment of surface contamination with petroleum hydrocarbons they are a refined version of land farming that tend to control physical losses of the contaminants by leaching and volatilization. Bio piles provide a favorable environment for indigenous aerobic and anaerobic microorganisms.

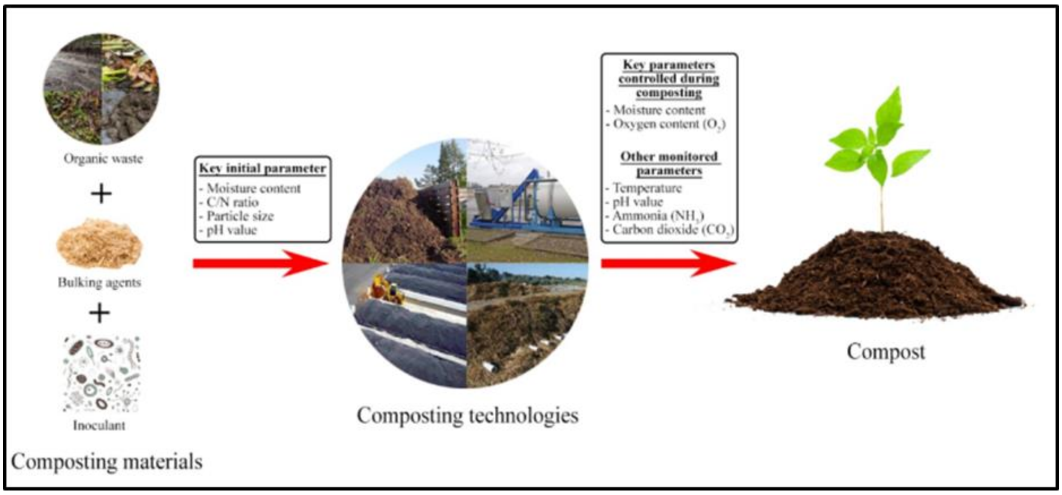


Figure 1.8: Composting

C. Bioreactors:

Bioreactors. Slurry reactors or aqueous reactors are used for ex situ treatment of contaminated soil and water pumped up from a contaminated plume. Bioremediation in reactors involves the processing of contaminated solid material (soil, sediment, sludge) or water through an engineered containment system. A slurry bioreactor may be defined as a containment vessel and apparatus used to create a three-phase (solid, liquid, and gas) mixing condition to increase the bioremediation rate of soil bound and water-soluble pollutants as a water slurry of the contaminated soil and biomass (usually indigenous microorganisms) capable of degrading target contaminants. In general, the rate and extent of biodegradation are greater in a bioreactor system than in situ or in solid-phase systems because the contained environment is more manageable and hence more controllable and predictable.

Despite the advantages of reactor systems, there are some disadvantages. The contaminated soil requires pretreatment (e.g., excavation) or alternatively the contaminant can be stripped from the soil via soil washing or physical extraction (e.g., vacuum extraction) before being placed in a bioreactor.

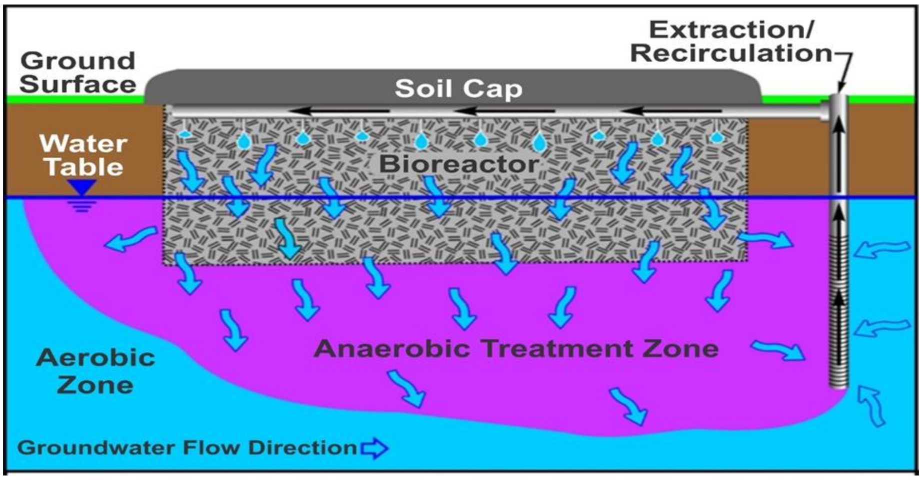


Figure 1.9: Bioreactors

Technology	Examples	Benefits	Limitations	Factors to consider
In situ	*In situ* bioremediation	Most cost efficient	Environmental	Bio degradative abilities of
	Bio sparging	Noninvasive	constraints	indigenous microorganisms
	Bioventing	Relatively passive	Extended treatment	Presence of metals and
	Bio augmentation	Natural attenuation	time	other inorganics
		processes	Monitoring difficulties	Environmental parameters
		Treats soil and water		Biodegradability of pollutants Chemical solubility Geological factors Distribution of pollutants
Ex situ	Land farming	Cost efficient	Space requirements	See above
	Composting	Low cost	Extended treatment time	
	Bio piles	Can be done on site	Need to control abiotic loss	

Technology	Examples	Benefits	Limitations	Factors to consider
			Mass transfer problem Bioavailability limitation	
Bioreactors	Slurry reactors	Rapid degradation kinetic	Soil requires excavation	See above
	Aqueous reactors	Optimized environmental	Relatively high cost	Bio augmentation
		parameters	capital	Toxicity of amendments
		Enhances mass transfer	Relatively high operating	Toxic concentrations of
		Effective use of inoculants and surfactants	cost	contaminants

D. Advantages of Bioremediation:

- Bioremediation is a natural process and is therefore perceived by the public as an acceptable waste treatment process for contaminated material such as soil. Microbes able to degrade the contaminant increase in numbers when the contaminant is present; when the contaminant is degraded, the bio degradative population declines. The residues for the treatment are usually harmless products and include carbon dioxide, water, and cell biomass.
- Theoretically, bioremediation is useful for the complete destruction of a wide variety of contaminants. Many compounds that are legally considered to be hazardous can be transformed to harmless products. This eliminates the chance of future liability associated with treatment and disposal of contaminated material.
- Instead of transferring contaminants from one environmental medium to another, for example, from land to water or air, the complete destruction of target pollutants is possible.
- Bioremediation can often be carried out on site, often without causing a major disruption of normal activities. This also eliminates the need to transport quantities of waste off site and the potential threats to human health and the environment that can arise during transportation.
- Bioremediation can prove less expensive than other technologies that are used for clean-up of hazardous waste.

E. Disadvantages of Bioremediation:

- Bioremediation is limited to those compounds that are biodegradable. Not all compounds are susceptible to rapid and complete degradation.
- There are some concerns that the products of biodegradation may be more persistent or toxic than the parent compound.

- Biological processes are often highly specific. Important site factors required for success include the presence of metabolically capable microbial populations, suitable environmental growth conditions, and appropriate levels of nutrients and contaminants.
- It is difficult to extrapolate from bench and pilot-scale studies to full-scale field operations.
- Research is needed to develop and engineer bioremediation technologies that are appropriate for sites with complex mixtures of contaminants that are not evenly dispersed in the environment. Contaminants may be present as solids, liquids, and gases.
- Bioremediation often takes longer than other treatment options, such as excavation and removal of soil or incineration.
- Regulatory uncertainty remains regarding acceptable performance criteria for bioremediation. There is no accepted definition of "clean", evaluating performance of bioremediation is difficult, and there are no acceptable endpoints for bioremediation treatments.

1.6 Phytoremediation:

Phytoremediation is the use of green plant removal of contaminants from contaminated soil, water, sediment and air.

The plant work with soil Organism to transform contaminant such as heavy metal and toxic organic component into harmless or valuable from.

Phytoremediation is an efficient selected or engineered plants are used in this process.

Remediation occur due to

- Accumulation of organic plant tissue.
- Translocation of the organic to leaf and volatilization from the leaf surface.
- The organism maybe metabolized in plant tissue or in the rhizosphere itself.
- Active microbial communities associated with plants assay degraded the organic contaminants.
- Phytoremediation has been obtained certain pesticides, trichloroethane and petroleum hydrocarbon but the overall rate and quantity is relatively slow.

Plants remove inorganic contaminants either by volatilization or by metal accumulation. The later mode is your generated application but plant biomass has to be removed and appropriately disposed.

Volatilization is used full for the removal of Hg Arabidopsis thaliana this genic plant absorb Hg^{++} and reduce to volatile Hg (o) which volatilizes from the leaf surface.

1.6.1 Method for Phytoremediation:

a. For metal contaminants phytoextraction Rhizofiltration phytostabilisation.
b. Method used to phytoremediation organic contaminant are

- phytodegradation
- Rhizodeqradation

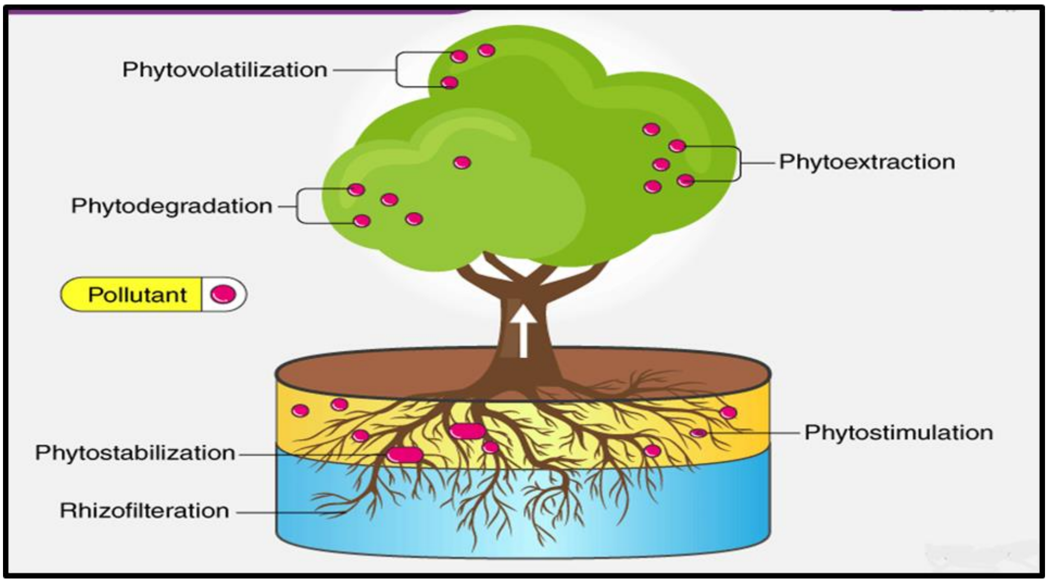


Figure 1.10: Hytoremediation

Method for metal contaminated site

A. Phyto extraction:

In this process plant root uptake heavy metal containment from the soil and translocate them to their above soil tissue.

It has been used when the contaminants contaminant site contain more than one type metal containment.

B. Rhizofiltration:

Rhizofiltration is similar in concept phyto extraction but it used in case of contaminated groundwater rather than the remediation of polluted soil.

The contaminant are either absorbed on to the root surface or absorbed by the plant root.

C. Phytostabilization:

Phytostabilization is the use of certain plants to immobilize soil and water contaminants.

Contaminant absorb and accumulated by root absorb on to the root surface or precipitated on the rhizosphere.

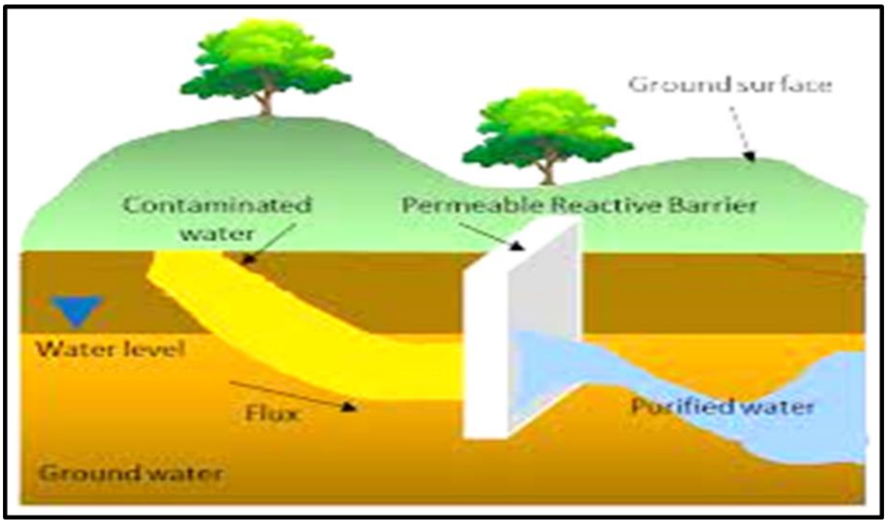
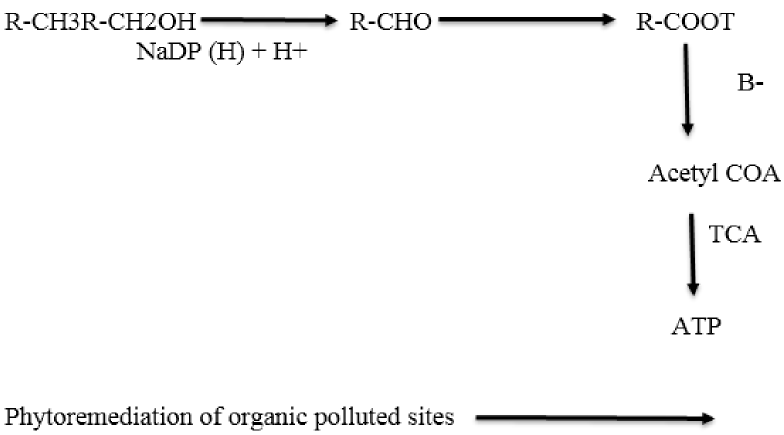


Figure 1.11: Phytostabilization



D. Phytodegradation:

Phytodegradation is the degradation or breakdown of organic containment by internal or external metabolic process driven by the plant.

Metabolic process hydrolyse organic compound into smaller units.

Chlorinated solvent such as TCE (trichloroethane) and other which the great organic herbicides.

E. Rhizodegradation:

Rhizodegradation is the breakdown of organic contaminants in the soil by soil during microbes which is enhanced by the rhizosphere present.

The plant root losing the soil and transport water to the rhizosphere thread is Sonali enhancing microbial activity.

F. Phytovolatilization:

Phytovolatilization is the process where plant after contaminant which are water soluble and release them into atmosphere.

The contaminant travels along the plant from root to leaves where by the contaminant evaporate into the air surrounding the plant.

Advantages of Phytoremediation:

- It is more economically stable.
- Disposal site are not needed.
- Present plants on site make them more authorative.

Disadvantages of Phytoremediation:

- it is dependent on the growing condition required by the plant
- Success is dependent on the plants to the pollutant.
- The contaminant must be present within the Jones of growing plants.

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