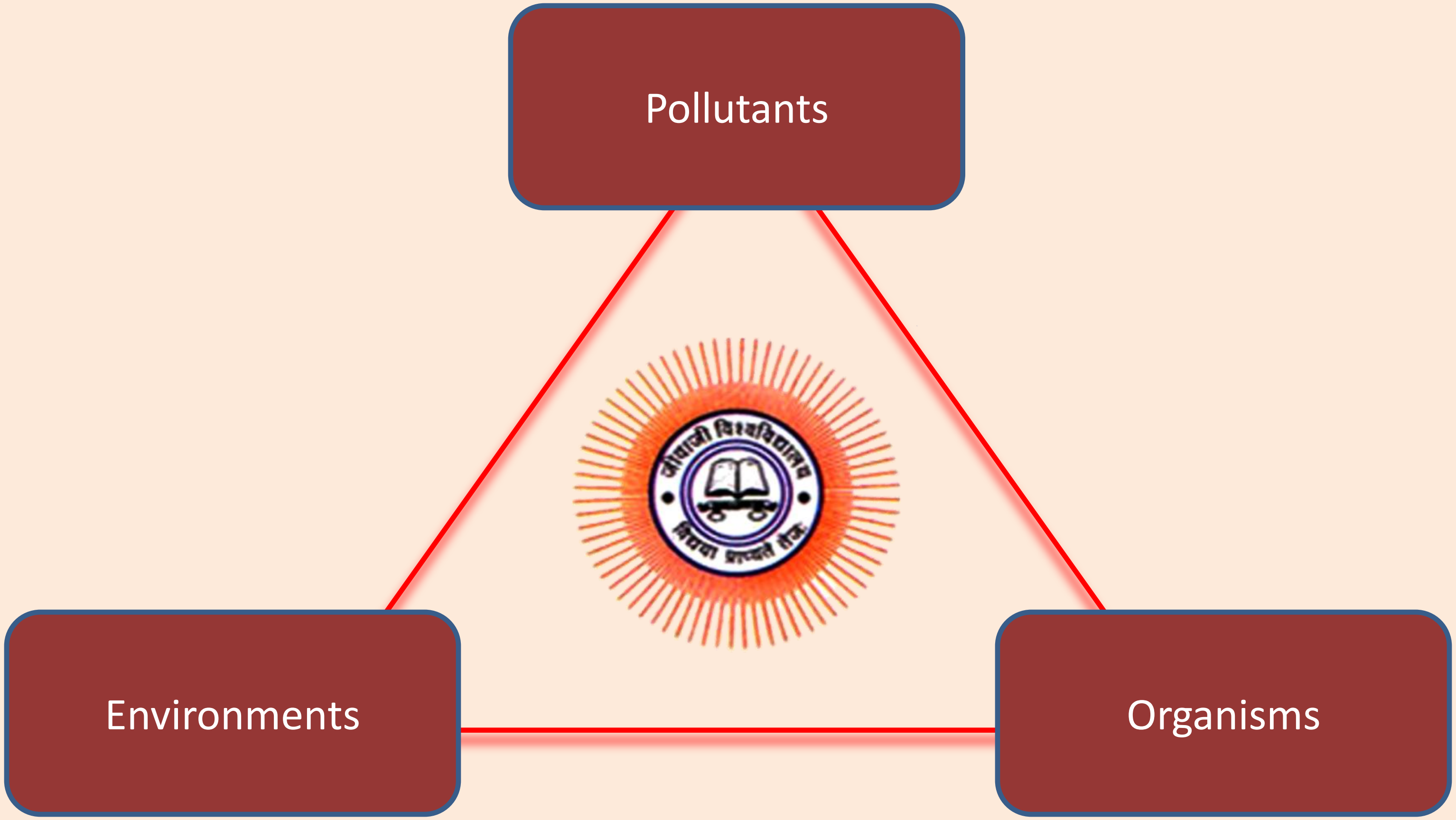
BIOREMEDIATION



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Introduction

- Bioremediation is defined as the use of biological organisms like bacteria, fungi and Plants to remediate, sequester or degrade the pollutants (inorganic and organic pollutants) from the environment.
- In the last few decades, the expansion of industrialization has lead to the release of a large no. of pollutants in environment

Environmental contaminants

Pollutants: Naturally-occurring compounds in the environment that are present in unnaturally high concentrations

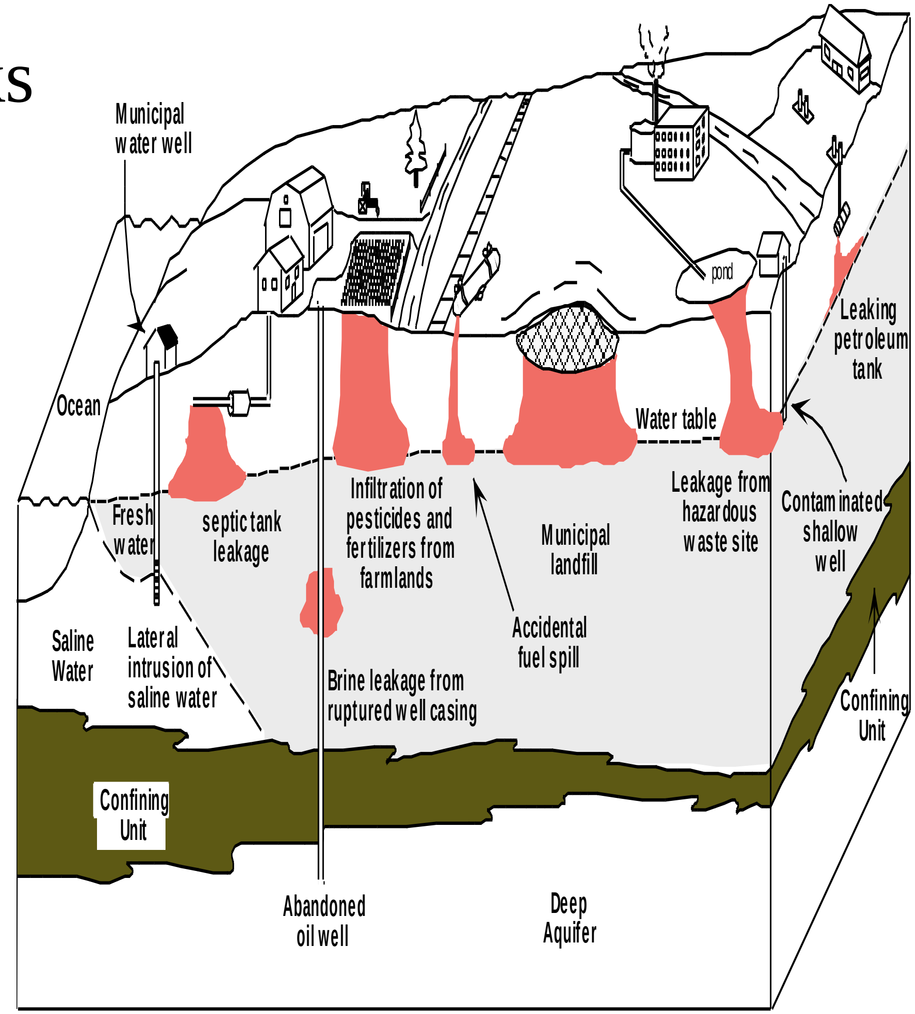
Examples: • Crude oil • Refined oil • Phosphates • Heavy metals

Xenobiotics: Chemically synthesized compounds that have never occurred in nature before

Examples: • Pesticides • Herbicides • Plastics

Sources of Contamination

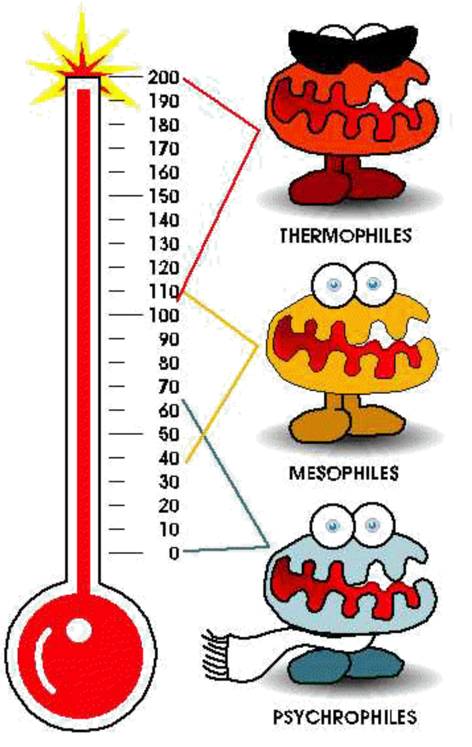
- Industrial spills and leaks
- Surface impoundments
- Storage tanks and pipes
- Landfills
- Burial areas and dumps
- Injection wells



Why to use Bioremediation?

There are a no. of physical and chemical methods available but why bioremediation because

- No additional disposal costs
- Low maintenance
- Does not create an eyesore
- Capable of impacting source zones and thus, decreasing site clean-up time



What Types of Organisms Have Been Used?

- Bacteria
  - ✓ The natural community
  - ✓ Bioaugmentation
- Fungi
- Plants (Phytoremediation)

What Types of Compounds Can Be Treated Biologically?

- Petroleum Hydrocarbons
  - Gasoline
  - Diesel Fuel
  - Gasoline Additives such as MTBE
- Polyaromatic Hydrocarbons
  - Creosote
- Chlorinated Hydrocarbons
  - Chlorinated Aliphatics: trichlorethylene
  - Chlorinated Aromatics : PCB's, Pentachlorophenol
- Explosives
  - RDX, TNT
- Inorganics via Reduction to a Lower Valence Causing Precipitation
  - Uranium, Technicium
  - Sulfur and Sulfuric Acid
  - Ammonia or Nitrate/Nitrite

Bioremediation strategies

- Bioremediation technologies can be generally classified as *in situ* or *ex situ*.
- *In situ* (in site) bioremediation involves treating the contaminated material at the site while *ex situ* (off site) involves the removal of the contaminated material to be treated elsewhere.
- Some examples of bioremediation technologies are bioventing, bioaugmentation, landfarming, bioreactor, composting, rhizofiltration, and biostimulation.

Bioventing

- Bioventing uses relatively low-flow soil aeration techniques to enhance the biodegradation of soils contaminated with organic contaminants.
- Although bioventing is predominantly used to treat unsaturated soils, applications involving the remediation of saturated soils and groundwater (augmented by air sparging) are becoming more common.
- Generally, a vacuum extraction, an air injection, or a combination of both systems is employed.
- An air pump, one or more air injections or vacuum extraction probes, and emissions monitors at the ground surface level are commonly used.

Bioaugmentation

- **Biological augmentation** is the addition of archae or bacterial cultures required to speed up the rate of degradation of a contaminant.
- Organisms that originate in a contaminated areas may be already able to break down waste, but ineffeciently and slowly.
- Bioaugmentation usually requires studying the indigenous varieties present in the location to determine if biostimulation is possible.
- If the indigenous variety do not have the metabolic capability to perform the remediation process, exogenous varieties with such sophisticated pathways are introduced.
- Bioaugmentation is commonly used in municipal wastewater treatment to restart activated sludge bioreactors.

Land Farming

- Ex situ processes also include landfarming, which involves spreading contaminated soils over a large area.
- Bioremediation may also be conducted in a bioreactor, in which the contaminated soil or sludge is slurried with water in a mixing tank or a lagoon.
- Bioremediation systems require that the contaminated soil or sludge be sufficiently and homogeneously mixed to ensure optimum contact with the seed organisms.

Biopile Treatment

- It is a full-scale technology in which excavated soils are mixed with soil amendments, placed on a treatment area, and bioremediated using forced aeration.
- It is a hybrid of landfarming and composting.
- The basic biopile system includes a treatment bed, an aeration system, an irrigation/nutrient system and a leachate collection system.

Key Features of Bioremediation

- Most bioremediation treatment technologies destroy the contaminants in the soil matrix.
- These technologies are generally designed to reduce toxicity either by destruction or by transforming toxic organic compounds into less toxic compounds.
- Indigenous micro-organisms, including bacteria and fungi are most commonly used.
- In some cases, wastes may be inoculated with specific bacteria or fungi known to biodegrade the contaminants in question. Plants may also be used to enhance biodegradation and stabilize the soil.
- The addition of nutrients or electron acceptors (such as hydrogen peroxide or ozone) to enhance growth and reproduction of indigenous organisms may be required.
- Field application of bioremediation may involve:
  - i. Excavation
  - ii. Soil handling
  - iii. Storage of contaminated soil piles
  - iv. Mixing of contaminated soils
  - v. Aeration of contaminated soils
  - vi. Injection of fluid
  - vii. Extraction of fluid
  - viii. Introduction of nutrients and substrates

Steps of degradation by Microorganisms

1- Isolation of the microorganism

2- Purification of the obtained isolates

3- Identification of the microbial isolate

4- Optimization of the biodegradation conditions

5- Determination of the biodegradation efficiency

6- Identification of the biodegradation products.

7- Cell or enzyme immobilization.

8- Enzyme identification.

Advantages of Bioremediation

- Bioremediation is perceived by the public as an acceptable waste treatment process.
- Microbes able to degrade the contaminant increase in numbers when the contaminant is present and when degraded, the biodegradative population declines.
- It is safe as the residues for the treatment are usually harmless products and include carbon dioxide, water, and cell biomass.
- It is useful for the complete destruction of a wide variety of contaminants. 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.
- It can often be carried out on site, without disruption of normal activities, no need to transport waste off site.
- It does not require too much of sophisticated equipment's.
- Bioremediation is less expensive than other technologies.

Disadvantages of bioremediation

- Bioremediation is limited to those compounds that are biodegradable. Not all compounds are susceptible to rapid and complete degradation.

- 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 for complex mixtures of contaminants that are not evenly dispersed in the environment.

- Bioremediation often takes longer than other treatment options, such as excavation and removal of soil or incineration.

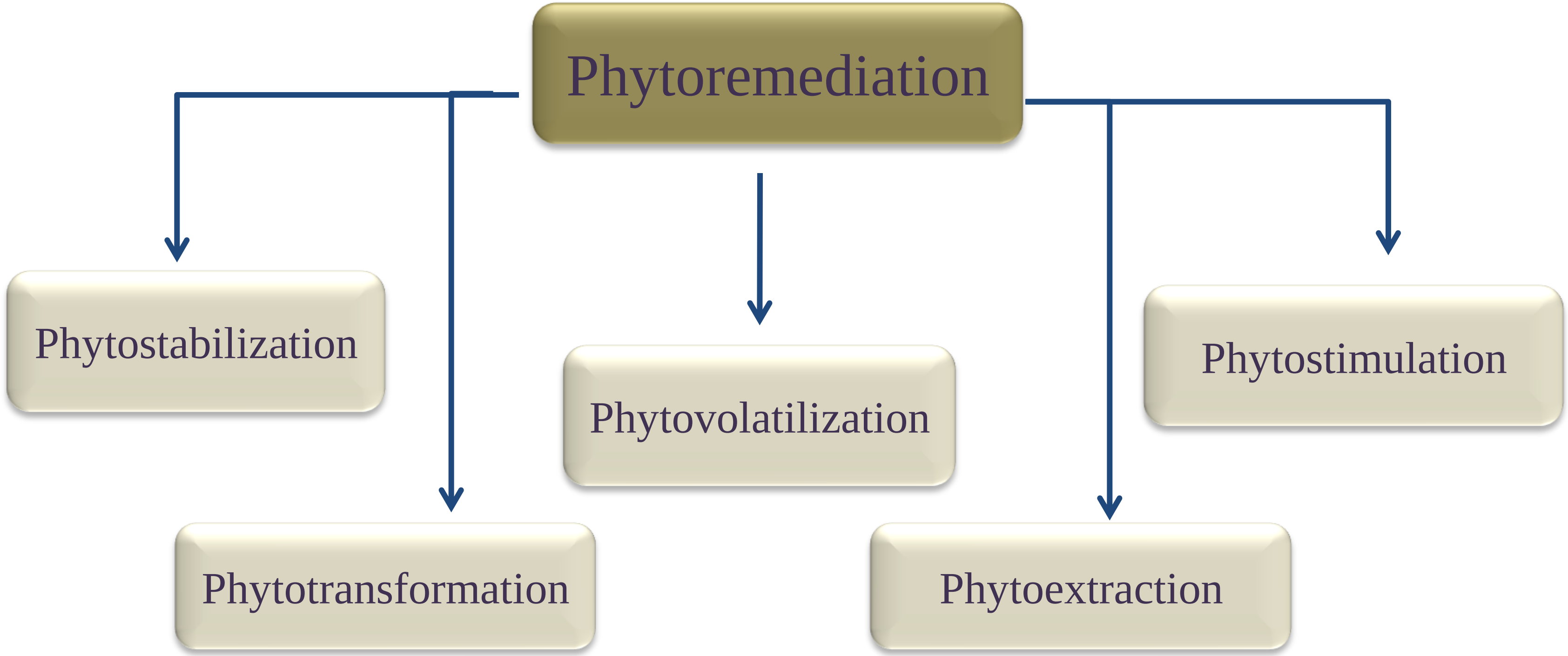
Bioremediation Status in India

- The country has so far, identified 172 abandoned dump sites located in various states which require remediation.
- So far, bioremediation in India appears techno economically feasible because of the prevailing tropical climate almost throughout the year in most of the States and Union Territories.
- Phytoremediation in India is being extensively used for restoration of environmental quality. However, there exists ample scope to modify the process through biostimulation and bioaugmentation as well as through better understanding of the behavior of microbial community. Also, the potential for generation of carbon credit through phytoremediation intervention as well as through solid waste composting (instead of land filling) needs to be identified and applied wherever possible.

Phytoremediation

Phytoremediation is use of plants for accumulation, removal or conversion of pollutants.

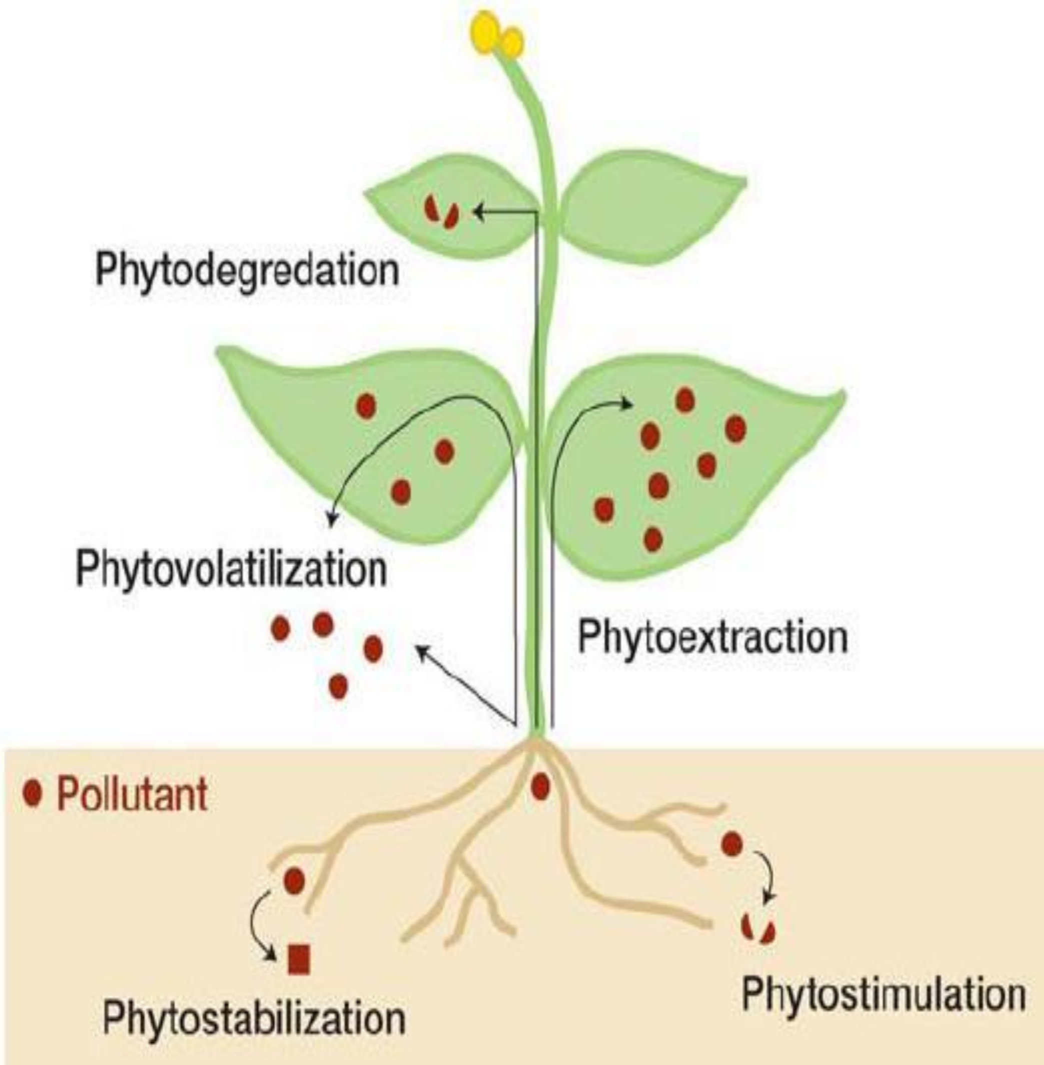
Based on the contaminant fate, phytoremediation may be of following types:



Phytoremediation overview

Table 5 Overview of phytoremediation applications.

Technique	Plant mechanism	Surface medium
Phytoextraction	Uptake and concentration of metal via direct uptake into the plant tissue with subsequent removal of the plants	Soils
Phytotransformation	Plant uptake and degradation of organic compounds	Surface water, groundwater
Phytostabilization	Root exudates cause metal to precipitate and become less available	Soils, groundwater, mine tailing
Phytodegradation	Enhances microbial degradation in rhizosphere	Soils, groundwater within rhizosphere
Rhizofiltration	Uptake of metals into plant roots	Surface water and water pumped
Phytovolatilization	Plants evaportranspirate selenium, mercury, and volatile hydrocarbons	Soils and groundwater
Vegetative cap	Rainwater is evaportranspirated by plants to prevent leaching contaminants from disposal sites	Soils


Phytodegredation
Phytovolatilization
Phytoextraction
Pollutant
Phytostabilization
Phytostimulation

- Approximately 400 plant species have been classified as hyperaccumulators of Contaminants like heavy metals, PAHs, Pesticides.
- Eg., grasses, sunflower, corn, hemp, flax, alfalfa, tobacco, willow, Indian mustard, poplar, water hyacinth, etc.

Advantages of Phytoremediation

- The cost of the phytoremediation is lower than that of traditional processes both *in situ* and *ex situ*
- It can be employed in areas that are inaccessible without excavation
- The plants can be easily monitored
- The possibility of the recovery and re-use of valuable metals (by companies specializing in “phyto mining”)
- It is potentially “the least harmful” method because it uses naturally occurring organisms and preserves the environment in a more natural state

THANK YOU