Bioremediation

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Bioremediation

- Bioremediation employs the living organisms, most notably microorganisms, to degrade the pollutants and convert them into less toxic or nontoxic form.
- The suitable organisms can be bacteria, fungi, or plants, which have the physiological abilities to degrade, detoxify, or render the contaminants harmless.
- Some contaminated soil and water conditions already have the right counter-microbes.
- Human intervention can speed up the natural remediation by boosting microbial action.
- A widely used approach to bioremediation involves stimulating naturally occurring microbial communities, providing them with nutrients and other needs, to break down a contaminant. This is termed biostimulation**.**
- **Biostimulation** can be achieved through changes in pH, moisture, aeration, or additions of electron donors, electron acceptors or nutrients.
- In other cases where the right microbes are low in numbers or entirely absent, bioremediation is introduced by adding amendments — microbial actors like fungi and aerobic bacteria that are mixed into the soil or water.
- This simple process is called **bioaugmentation**, and it's highly effective to correct conditions quickly, as long as the right environmental conditions are present.
- Overall, bioremediation technique depends on having the right microorganisms in the right place under the suitable environmental conditions in order for the degradation process to occur successfully.

Factors affecting microbial bioremediation

- These factors included are:
  - the existence of a microbial population capable of degrading the pollutants,
  - the availability of contaminants to the microbial population and environment factors (type of soil, temperature, pH, the presence of oxygen or other electron acceptors, and nutrients).
- **Biological factors:**
  - competition between microorganisms for limited carbon sources,
  - antagonistic interactions between microorganisms or
  - the predation of microorganisms by protozoa and bacteriophages.
- **Environmental factors:** Microorganism growth and activity are affected by 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).

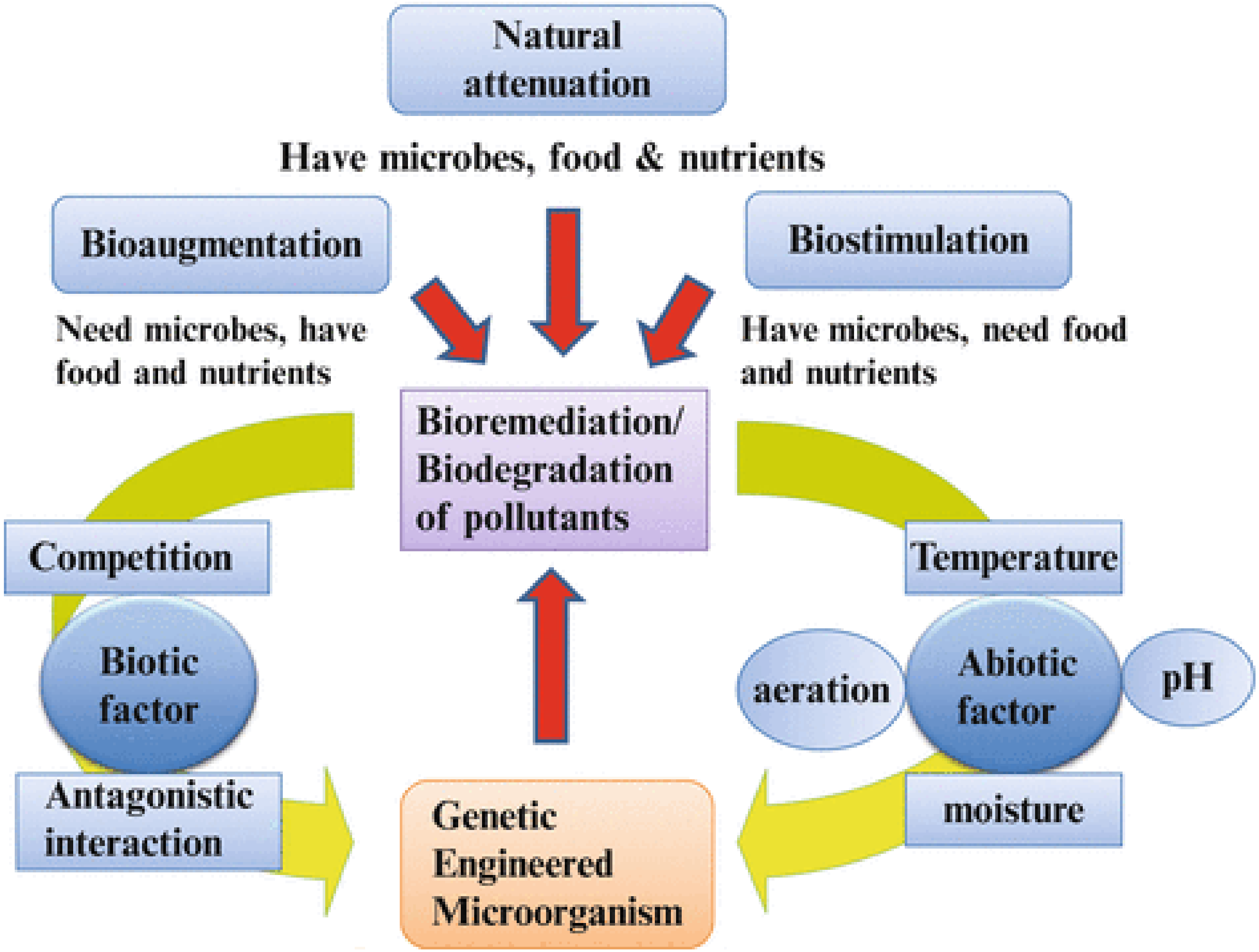
...Factors affecting microbial bioremediation

- Nutrient balancing especially the supply of essential nutrients such as N and P can improve the biodegradation efficiency.
- The addition of an appropriate quantity of nutrients is a favourable strategy for increasing the metabolic activity of microorganisms and thus the biodegradation rate in cold environments.
- The best known application of oleophilic fertilizers (concretely Inipol EAP 22) took place during the remediation of Exxon Valdez oil spill in Alaska.
- The original product (lauryl phosphate, urea, oleic acid, 2-butoxy -1-ethanol and water; C:N:P = 62:5:1) was designed by Elf Aquitaine after Amoco Cadiz oil spill in France in 1978.
- Temperature also speed up or slow down bioremediation process because highly influence microbial physiological properties.

...Factors affecting microbial bioremediation

- Biological degradation is carried out in aerobic and anaerobic condition.
- The presence of oxygen in most cases can enhance hydrocarbon metabolism.
- Biodegradation can occur under a widerange of pH; however, a pH of 6.5 to 8.5 is generally optimal for biodegradation in most aquatic and terrestrial systems.
- Moisture influences the kind and amount of soluble materials that are available as well as the osmotic pressure and pH of terrestrial and aquatic systems.
- Metals are important in small amount for bacteria and fungus, but in high quantity inhibit the metabolic activity of the cells.
- When in high concentrations of toxic nature of some contaminants, can create toxic effects to microorganisms and slow down decontamination.

Overview of bioremediation



Bioremediation Classes/types

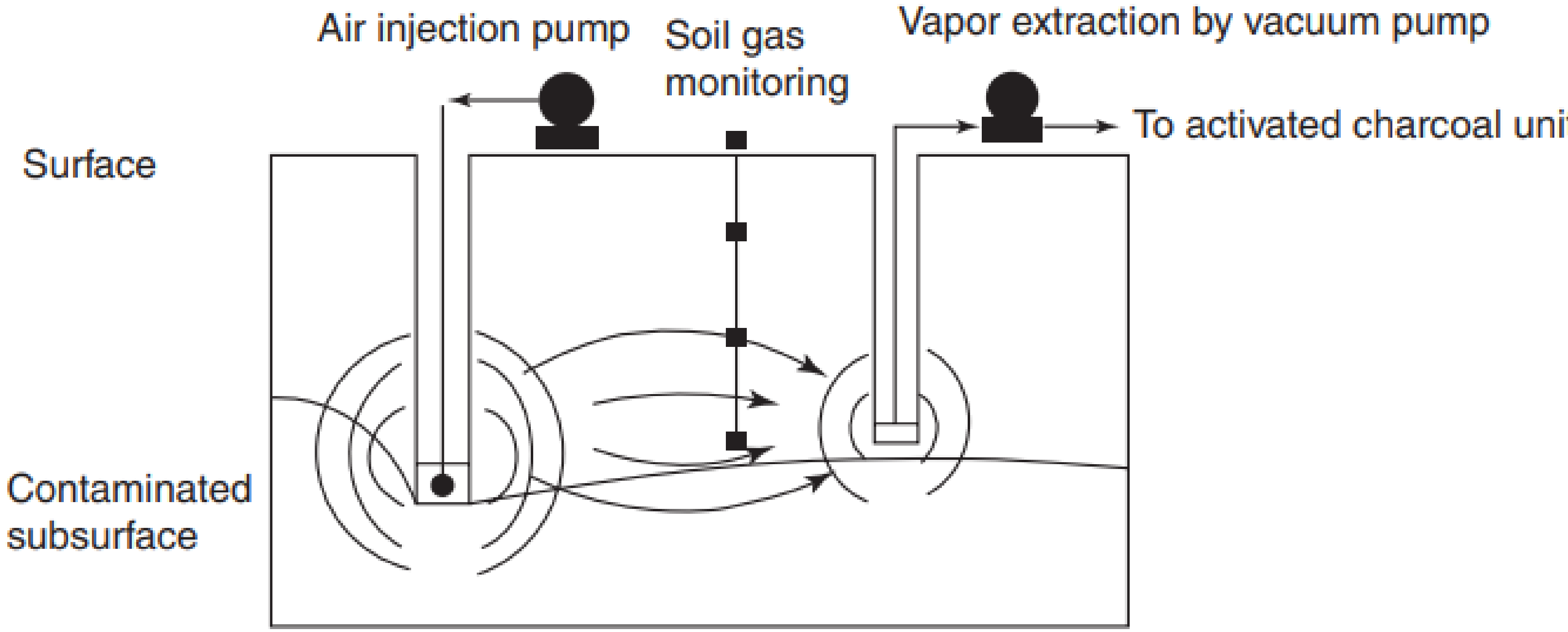
- There are two main classifications of bioremediation.
- **In situ,** where all bioremediation work is done right at the contamination site.
- This can be polluted soil that's treated without unnecessary and expensive removal, or it can be contaminated groundwater that's remediated at its point of origin.
- In situ is the preferred bioremediation method, as it requires far less physical work.
- Bioventing, biosparging and bioaugmentation are the main technique classes.
- **Ex situ** means removing contaminated material to a remote treatment location.
- This classification is less desirable as it involves the big job of excavating polluted soil and trucking it offsite.
- In the case of contaminated water, ex situ is rare, except for pumping groundwater to the surface and biologically treating it in an enclosed reservoir.
- Ex situ bioremediation poses a hazard to spreading contamination or risking an accidental spill during transport.
- Once at an ex situ treatment site, three technique classes can be applied.
  - One is land farming, where soil is spread and biologically decontaminated.
  - Another is composting, which is an age-old process.
  - The third class involves bioreactors.

In situ Bioremediation techniques/ Strategies

Bioventing: is the most common approach.

- The operating principle of bioventing relies on the supply of air and nutrients through specifically constructed wells to contaminated soil, so as to stimulate the indigenous microorganisms.
- Bioventing technology employs relatively low air flow rates, which not only provides the oxygen required for biodegradation to occur but also minimizes the volatilization and release of contaminants to the atmosphere.
- Nitrogen and phosphorus are often required because contaminated soil has been depleted of these macronutrients due to biodegradation of the increased carbon loading by petroleum hydrocarbons. Oleophilic fertilizers (those with an affinity for oils) are widely used as they adhere to hydrocarbons, providing nutrients at the oil–water interface.
- Bioventing can be classified into active or passive technology.
- In passive technology the gas exchange through the vent wells occurs only by the effect of atmospheric pressure.
- In active technology the air is driven into the ground through a blower or a pump.
- Bioventing is highly efficient especially for hydrocarbon-contaminated sites

Bioventing technology



...In situ Bioremediation techniques/ Strategies

Biosparging:

- Biosparging is the technology in which air is injected under pressure to groundwater in order to increase the oxygen concentration, thus enhancing the biological degradation rate by the presence of indigenous microbial populations.
- The major advantage of this technology is the relatively easy and low-cost installation of the (especially small diameter) air injector points, which provides flexibility in the design, construction, and operation of such treatment systems.

...In situ Bioremediation techniques/ Strategies

Bioaugmentation:

- It is often used to add extra indigenous microbes or to implant exogenous species to the site. Eg. *Pseudomonas, Corynebacterium, Arthrobacter, Mycobacterium, Nocardia, Phanerochaete chrysosporium*, *Candida, Gibeberella.*
- It is well established that bioaugmentation is an efficient technology in both laboratory and field applications for the removal of organic contaminants, such as benzene, toluene, or chlorinated organic compounds.
- Augmentation works in conjunction with both bioventing and biosparging applications, but has limitations.
- The nonindigenous microbial population usually find severe difficulties to compete well enough with an indigenous population.

...Bioagumentation

- Therefore, the added microbial culture should also have the ability to withstand different soil conditions and to survive in the presence of other microbial population.
- An attractive approach is to rapidly increasing the natural microorganism population growth and enhance degradation that preferentially feed on the contaminants site.
- Microbes are collected from the remediation site, separately cultured, genetically modified and returned to the site.
- Natural species are not fast enough to break down certain compounds so to facilitate must be genetically modified through DNA manipulation.
- Genetically engineered microorganisms (GEMs) highly compete with the indigenous species, predators and also various abiotic factors.

...Bioagumentation

- As early as 1972, Ananda Chakrabarty, of the University of Illinois in Chicago, made global headlines in his attempt to patent a genetically modified *Pseudomonas* strain able to degrade a suite of petroleum components and thus holding a potential for dissipating oil spills.
- GEMs have shown potential for bioremediation of soil, groundwater and activated sludge, exhibiting the enhanced degrading capabilities of a broad coverage of chemical and physical pollutants.

GEMs	XENOBIOTICS
Pseudomonas putida	Mono-and dichloro aromatic compounds
P.diminuta	Parathion
P.oleovorans	Alkane
P.cepacia	2,4,5-Trichlorophenol
Acinetobacter species	4-Chlorobenzene
Alcaligenes species	2,4-Dichlorophenoxy acetic acid

Ex situ Bioremediation techniques/ Strategies

Land farming:

- This is a simple technology, in which contaminated soil is removed and spread over a prepared surface area and periodically tilled, until natural degradation occurs.
- The treated material is placed in windrows or lined cells or treatment beds, and the required oxygen is supplied by tilling or forced aeration.
- When necessary, inorganic nutrients are simultaneously supplied to the system.
- The goal of this technology is to stimulate the indigenous microbial populations for the aerobic degradation of the pollutants.
- In general, the active area of microbes is limited to the superficial 15–30 cm of soil.
- Soil nutrients, pH, buffer capacity (lime requirements), and moisture are constantly monitored and adjusted favorably to the biodegradation.
- Inadequate moisture disturbs the osmotic balance between the microbial organism and the medium, whereas excess moisture compromises the air transport due to water clogging.
- The advantages of this technology include mainly: (1) a significant reduction of surface area required for treatment, (2) reduced remediation time due to improved design, and (3) ease of applied treatment.

...Ex situ Bioremediation techniques/ Strategies

Composting:

- Composting is a biological process that is described as the combination of contaminated material with nonhazardous organic amendments, such as manure or agricultural wastes.
- This mixture facilitates the development of a rich microbial population, consisting mainly of mesophilic and thermophilic microorganisms.
- Therefore, the optimal composting environment is characterized by elevated temperatures (50°C), excessive nutrients, high moisture level, nonlimiting oxygen, and neutral pH.
- The major advantage of composting, when compared to land farming, is that it enables the improved control and optimization of the process, so that the rate and extent of microbial activity become significantly better than those in land farming.
- Composting is also considered a feasible option for detoxifying, degrading, or inactivating hazardous wastes.
- The composting methodology in that case does not differ greatly from the methodology applied for nonhazardous materials.

...Ex situ Bioremediation techniques/ Strategies

Bioreactors :

- Bioreactors are used for treatment of contaminated soil, or of water coming from a contaminated plume.
- This technology offers through the control of critical parameters, such as microbial population, nutrients, pH, and moisture, the near-perfect environment for biodegradation.
- In simple words, a bioreactor is a reaction vessel equipped with a mixing system, a system supplying oxygen and nutrients and influent and effluent pumps.
- It can be run in batch or continuous mode.
- There are several types of bioreactors, namely submerged fixed-film, plug flow, fluidized bed, sequencing batch, slurry reactors, and vapor phase bioreactors.
- However, there are also some inevitable disadvantages:
  - excavation of soil and pumping of groundwater are necessary,
  - during the application of treatment a certain amount of sludge (treated material plus biomass) and a volume of gases (e.g., carbon dioxide, methane, hydrogen sulfide) are produced, considered eventually as secondary pollutants, which require further treatment, thus considerably

Questions

- Define bioremediation. What are the types of bioremediation discuss in detail.
- Write short note on:
  - Bioremediation types
  - Bioremediation techniques
  - Bioremediation strategies
  - Bioagumentation
  - Biostimulation
  - Factors affecting microbial bioremediation
  - In situ bioremediation
  - Ex situ bioremediation
  - Bioremediation of polluted water
  - Explain bioremediation of polluted soil