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POTENTIAL OF MICROBES IN DECONTAMINATING AGRICULTURAL SOILS

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Lorenz Hiltner, a pioneer in rhizosphere microbial nature and soil bacteriology research, when properly cited soil as the wellspring of endless life because of the wide scope of capacities it performs. There is no denying in the way that "A healthy soil is the backbone of agriculture." Soil health is the condition of the soil concerning its inherent (or potential) capability to sustain biological productivity, maintain environmental quality, and promote plant and animal health.

Therefore, healthy soil is productive, sustainable, and profitable. Industrialization and modernization have adverse effects on soil health, leading to its degradation of land. Bioremediation is the process by which living organisms degrade hazardous pollutants. Among different bioremediation methods, microbial metabolism is accepted as a safer and efficient tool for the removal of many pollutants. Different bioremediation approaches have been successfully applied for the removal of soils contaminated with a variety of xenobiotic compounds. Pesticides have been the major source of contamination in agricultural soils for years. These chemicals tend to persist in the soil for years and bioaccumulate and biomagnify in the food chain, finally entering the human body cause health risks. Heavy metals are another major source of contamination that has gained importance in recent years. Genetically engineered microorganisms (GEMs) are playing an increasingly important role in tackling soil contamination.

What is Soil Contamination?

Soil contamination occurs when the concentration of chemicals, nutrients, or elements in the soil becomes more than it normally or naturally is due to human action. If this contamination goes on to harm living organisms, we may call it pollution. Soil Science Society of America defined soil contamination as "Any substance in the soil that exceeds naturally-occurring levels and poses human and soil health risks is a soil contaminant."

Examples of soil contaminants include chlorinated solvents, trinitrotoluene (TNT), heavy metals, pesticides, aromatic hydrocarbons (benzene, toluene, etc.), polyaromatic hydrocarbons.

Agricultural Activities as a Major Cause of Soil Contamination

Compound usage has gone up hugely since innovation furnished us with present day pesticides and composts. They are brimming with synthetic substances that are not created in nature and can't be separated by them. Therefore, they saturate the ground after they blend in with water and gradually decrease the fruitfulness of the dirt. Different synthetic substances harm the piece of the dirt and make it simpler to dissolve by water and air. Plants ingest a significant number of these pesticides, and when they decay, they cause soil contamination since they become a piece of the land.

Bioremediation

Bioremediation is defined as the process by which microorganisms are stimulated to rapidly degrade hazardous pollutants to environmentally safe levels in soil, sediments, substances, materials, and groundwater.

For bioremediation to be effective, microorganisms should enzymatically attack the contaminations and convert them to innocuous items. As bioremediation can be useful just where ecological conditions permit microbial development and action, its application regularly includes the control of natural boundaries to permit microbial development and continue to degrade at a quicker rate. Microorganisms have certain catalysts that utilize natural impurities as food, and as a result of their small size, they can contact toxins without any problem.

Microorganisms used in Bioremediation: We can subdivide these microorganisms into the following groups:

- **Aerobic bacteria:** It requires oxygen for functioning. They have the ability to degrade pesticides and hydrocarbons. Examples of aerobic bacteria having such degradative abilities include *Pseudomonas*, *Alcaligenes*, *Sphingomonas*, *Rhodococcus*, and *Mycobacterium.* These utilize contaminants as the sole source of carbon and energy.

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- **Anaerobic bacteria:** It does not require oxygen for functioning and is less frequently used than aerobic bacteria. The use of anaerobic bacteria for bioremediation of polychlorinated biphenyls (PCBs) in river sediments, dechlorination of the solvent trichloroethylene (TCE), and chloroform is gaining interest.

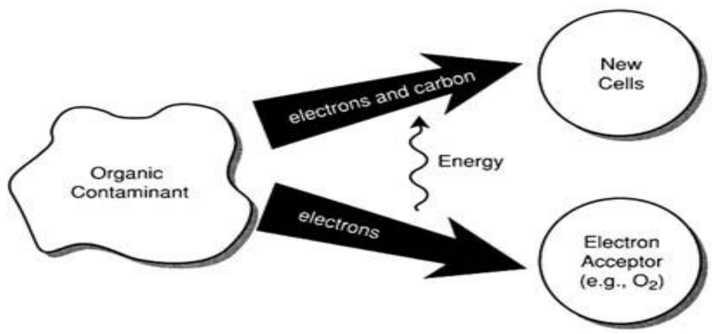
- **Methylotrophs:** These are aerobic bacteria that grow by utilizing methane as a source of carbon and energy. The initial enzyme in the pathway for aerobic degradation, methane monooxygenase, has a broad substrate range and is active against a wide range of compounds, including the chlorinated aliphatics trichloroethylene and 1,2-dichloroethane.

- **Ligninolytic fungi: these include** fungi such as the white rot fungus *Phanaerochaetechrysosporium*that can degrade an extremely diverse range of persistent or toxic environmental pollutants. The common substrates used include straw, sawdust, or corn cobs.

Microbial Metabolism

Contaminants may serve as:

1. Primary substrate- enough available to the sole energy source.
2. Secondary substrate- provides energy, not available in high enough concentration
3. Co-metabolic substrate- utilization of a compound by a microbe relying on some other primary substrate.



Organic contaminants serve two purposes for organisms firstly, as a source of carbon, and secondly, as the provision of electrons. Microorganisms degrade contaminants in light of the fact that in the process, they acquire energy that permits them to develop and repeat.

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Microorganisms get energy from the impurities by breaking substance bonds and moving electrons from the pollutants to an electron acceptor, like oxygen. They "contribute" the energy, alongside certain electrons and carbon from the pollutant, to create more cells.

Variations on Basic Metabolism

Aerobic respiration	• Molecular oxygen acts as electron acceptor
Anaerobic respiration	• Inorganic compounds acts as an electron acceptor
Inorganic Compounds as Electron Donors	• Electron acceptor is usually oxygen molecule
Fermentation	• Organic contaminant acts both as an electron acceptor and electron donor
Secondary Utilization and Co-metabolism	• Incidental reaction catalysed by enzymes
Reductive Dehalogenation	• Halogen atom is replaced with a hydrogen atom.

Major Contaminants of Agricultural Soils

A. PESTICIDES

Undoubtedly, pesticides are one of the major contaminants of agricultural soils. About 4 million tonnes of pesticides are applied to agricultural crops annually for pest control worldwide, and less than 1% of total applied pesticides generally get to the target pests. When pesticides are applied to soil, these tend to persist in the soil for several days. Apart from persistence, pesticides also tend to biomagnify and bioaccumulate.

- ✓ The Indian pesticide industry is the biggest in Asia and 12th in the world.
- ✓ The pesticide market is expected to grow at 12-13% per annum to reach $6.8billion(2017)
- ✓ Cotton and paddy are the crops with a maximum pesticide consumption rate of 50% and 18% resp. (*Source*: agropages.com)

For example, the microbial degradation of Atrazine occurs in two ways-

1. Decholrination by *Pseudomonas* sp.

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2. Dealkylation by *Aspergillus fumigatus* followed by dehalogenation by a *Rhodococcus* strain and by two *Pseudomonas* sp. strains.

B. HEAVY METALS

Heavy metals can be described as any metallic elements which have a relatively high density and are poisonous even at very low concentrations in every organism. These groups of metals and metalloids have atomic densities greater than 4 $gm/cm^{3,}$ which is five times higher than water.

The significant contributions of heavy metals (for example, lead, cadmium, arsenic, mercury) into farming frameworks are composts, pesticides, natural squanders like excrement, wastewater water system, and environmental stores. These are extremely persistent, non-biodegradable, non-thermo degradable consequently promptly gather to harmful levels. Some cultivating methods, similar to water systems can prompt the accumulation of selenium (Se), bringing about downstream water supplies containing concentrations of selenium that are harmful to untamed life, animals, and people. This interaction is known as the "KestersonEffect". Heavy metals seriously degrade the soil quality, development, and yield of crop plants, quality of agricultural products, and pose genuine dangers to animals and people.

Heavy metals don't undergo degradation yet change their chemical forms (speciation), and bioavailability is, notwithstanding, conceivable. These can be consumed by microorganisms at cellular binding sites. Extracellular polymers of these organisms can complex heavy metals through different mechanisms. The microbes prevalent in heavily metal-contaminated soil can alter the oxidation state of the heavy metals by immobilizing them, permitting them to be effectively eliminated. Bioremediation of heavy metals from microbes isn't vigorously investigated, generally because of inadequate comprehension of the genetics of the microbes used in metal adsorption.

- ✓ *B. subtilis* have been reported to reduce selenite to the less toxic elemental Se.
- ✓ Several microorganisms, especially bacteria (*Bacillus subtilis, Pseudomonas putida, and Enterobacter cloacae*) have been successfully used for the reduction of Cr (VI) to the less toxic Cr (III)

- ✓ *Desulfovibrio desulfuricans* converts sulphate to hydrogen sulphate which reacts with heavy metals such as Cd and Zn to form insoluble forms of these metal sulphides.

Genetically Engineered Microorganisms (GEMs)

GEMs are playing an increasingly important role in tackling soil contamination. Naturally-occurring chemicals can be broken down by microbes that have evolved for the purpose. However, man-made chemicals found in cosmetics, pesticides, insecticides, cleaners, and paints cannot be degraded into less toxic products by naturally occurring microbes.

- ✓ *Pseudomonas putida* was the 1st genetically engineered strain that is capable of utilizing complex chemical compounds like hydrocarbons
- ✓ *Deionococcus radiodurans*, a soil bacterium capable of breaking down radioactive mercury and toluene. It is listed as the world's toughest bacterium in the Guinness book of world records
- ✓ *Stenotrophomonas* sp. strain YC-1 was genetically engineered to produce an organophosphorus hydrolase (OPH) enzyme, which could degrade a mixture of six synthetic organophosphate pesticides completely within 5 hours.
- ✓ *Pseudomonas cepacia* RHJ1, a recombinant strain created by performing conjugation between *R.eutropha* JMP134(2,4D degrader) and *B.cepacia*AC1100(2,4,5 trichloro phenoxy acetate degrader) has been reported to degrade the herbicides mixture simultaneously.

Conclusion

Bioremediation is an exceptionally promising innovation for remediation, cleaning, managing, and recovering techniques for solving contaminated soils through microbial activity. It's anything but a natural and financially powerful remediation elective that can be applied to an expansive scope of contaminants. 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. Also, there is a strong need to carry out work on the unculturable microorganisms and their activities during biodegradation using advanced techniques like denaturing gradient gel electrophoresis(DGGE) and other cultivation independent techniques.

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