BIOREMEDIATION A SUSTAINABLE APPROACH TO POLLUTION

Abstract

The breakneck increase in human development and progress is also adversely affecting the population by introducing toxic chemicals into nature. To reduce its concentration, one such method devised is bioremediation. It is efficient, environmental friendly, and cost- effective, used for the detoxification of pollutants from the environment.

Keywords: Human development, toxic chemicals, bioremediation, detoxification.

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I. INTRODUCTION

The increasing population is leading to a higher rate of urbanization and demand for the production of daily household materials. Industrial productions release harmful pollutants such as particulate matter, carbon monoxide, heavy metals, plastic wastes, and microplastics which accumulate in the environment over a period of time. Some of the other types of waste materials like raw sewage, sanitary napkins, diapers, and plastic bags are dumped into landfills leading to decreased soil fertility, a pungent smell in the neighbourhood,etc.

II. WHAT IS BIOREMEDIATION

To reduce the harmful levels of such pollutants many physical, chemical, and biological techniques such as incineration, and photodegradation. One such biological technique is Bioremediation. Bioremediation was discovered by George. M. Robinson in the year 1960. He worked on oil-degrading microbes and was used on a large scale for cleaning of sun oil pipeline spill at Ambler; Pennsylvania in the year 1972. It is a process that uses living organisms such as microorganisms, to reduce levels of pollutants in the environment. ‘Bio’ means living and ‘remediation’ means to resolve (which literally translates to resolve using living organisms.) The biological agents used for the degradation of contaminants are known are bioremediates.

III. TYPES OF BIOREMEDIATION

Bioremediates can be of different types, some of the important ones are using bacteria, fungi, worms, and plants. Bioremediation using bacteria is known as microbial remediation, bioremediation using fungi is known as mycoremediation, bioremediation using worms is known as vermiremediation, and bioremediation using plant is known as phytoremediation. A number of criteria, including the concentration and chemical characteristics of the contaminant, the site of occurrence, and the nutritional, atmospheric, and temperature requirements needed for optimal growth must be taken into consideration for bioremediation to be effective.

IV. MICROBIAL BIOREMEDIATION

Bacteria are microorganisms belonging to the Kingdom Monera. Microbial bioremediation uses these bacteria that are either aerobic or anaerobic in nature that help in the biodegradation of contaminants, by which their concentrations can be brought to safer limits. This type of bioremediation uses microorganisms or their derivatives to reduce the concentration of toxic elements. Different bacteria such as Pseudomonas sp., Dechloromonas sp., Bacillus etc., are mostly used in bioremediation. These bacteria break down or degrade the pollutants by their inherited natural mechanisms resulting in biodegradation or biotransformation which in turn convert harmful substances present in wastewater, polluted soil, and oil spills (Fig.1) into simpler hydrocarbons. Different pathways can be adapted by the microbe for detoxification such as:

1. **Biosorption** by bacterial cells through cell surface adsorption, extracellular precipitation, and intracellular accumulation through special components- biosorption is

a process of binding of heavy metals, dyes or other metals to the cell walls of bacteria.

Volesky defined biosorption as the adsorption of substances from a solution by biological materials using physiochemical pathways of uptake, such as electrostatic forces and ion/proton displacement. The accumulation of substances by biosorption is known as bioaccumulation.

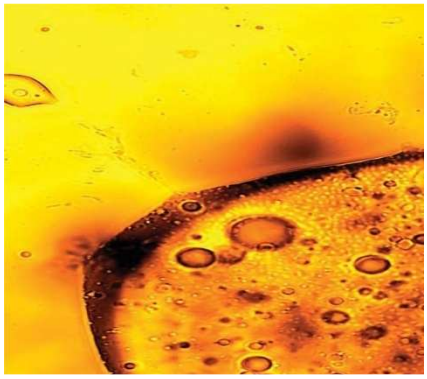

Figure 1: Oil-Eating Bacteria

Eg: Gram-positive bacteria such as *Bacillus* have shown to be more effective in the bioaccumulation process due to their thick peptidoglycan layer in the cell wall.

2. **Remediation Via Siderophore Formation:** siderophores are formed by bacteria due to iron deficiency in them. These siderophores pick up iron from their environments and bind to them, which the bacteria intakes. This method can be exploited for microbial bioremediation.

3. **Mechanism of Bacteria through Biosurfactant Production:** biosurfactants are microbial excretes that the bacteria produce to reduce intersurface tension. Products such as glycolipids and fats can be obtained. This mechanism is mainly used by bacteria like *Pseudomonas putida* for bioremediation of oil spills.

V. MYCO REMEDIATION

Fungi are known as the ultimate degraders of complex organic matter, involved in decay processes, and known to degrade wood including lignin and cellulose, and other plant- based materials, which are common waste products in agriculture. They can also degrade a variety of pollutants, such as heavy metals, insecticides, and petroleum compounds. They are useful for cleaning up the environment since they can absorb and store pollutants in their fruiting bodies. Most of the fungi are aerobic and are present in marine environments which degrade microplastics present in oceans. Mycoremediation, the practice of employing fungi to break down and remove pollutants from soil, water, and air, involves a considerable contribution from fungi species. Fungi are useful in this process because they possess special qualities for metabolizing different types of contaminants. Fungi have enzymatic machinery both inside and outside of their cells, and they can secrete acids, which allows them to attack and metabolize a variety of compound types, including both inorganic and organic contaminants. Highly used fungi are mushrooms of different kinds and white rot wood fungus *(Fig.2).* These help in bioremediation by degrading

lignocelluloses using extracellular enzymes. They can also be grown on any carbon source, which will be utilized and bio-transformed into other simpler substances.

Figure 2: White Rot Wood Fungus

Furthermore, advances in Recombinant DNA technology and Genetic engineering have opened up new possibilities for improving the efficiency and specificity of bioremediation using bacteria and fungi. For example, they can be engineered to produce enzymes that break down specific substances and can be further exploited.

VI. PHYTOREMEDIATION

Phytoremediation is the use of plants and soil-associated microorganisms to reduce the toxicity of contaminants. Plants are able to absorb and break down pollutants through a variety of mechanisms, including Phytostabilization, phytoextraction, and biofiltration. These processes involve the use of specific plant species that are able to tolerate and accumulate high levels of contaminants.

Figure 3: *Brassica juncea*

1. **Phytostabilisation:** In this process, plants tend to accumulate metals near their rhizosphere and help stabilize it by mobilizing it with a substrate.

2. **Phytoextraction:** In this process, the plants accumulate pollutants in their rhizosphere and mobilize them for uptake by plant roots to aerial parts of a plant and destroy organic pollutants by degradation process known as phytodegradation.

3. **Biofiltration:** This process is carried out by water plants which help in the uptake of

water contaminants to the aerial parts of the plant. Phytoremediation has been used successfully to clean up contaminated sites, such as abandoned industrial areas and landfills. It has also been used to treat wastewater and air pollution. White willow, Indian grass, poplar trees, Indian mustard, sunflower, and water hyacinth are the best plants for phytoremediation. These plants clean the soil and water of pollutants and heavy metals.

VII. VERMIREMEDIATION - INTRODUCTION

Earthworms are known as a farmer's friend due to their ability to help in increasing soil fertility. They help in increasing the availability of nutrients in the soil, better cycling of elements, removing unwanted debris, and helping in maintaining soil structure. Earthworms are mainly used for the preparation of different types of vermicompost. In India, different types of earthworms are used for preparing vermicompost depending on the requirements and are further used as manure for plant growth. It is a sort of compost made of nutrients enhanced by adding earthworms which are created by feeding the organic waste products to earthworms, who then digest and excrete the material which is nutrient-rich and microorganism-rich, soil-health-enhancing compost. Vermiremediation which is also known as "earthworm facilitated remediation", is a type of bioremediation that is carried out by preparing vermicompost using different species of earthworms, using them for bioremediating different contaminants by detoxifying them. It is a natural, aerobic, odorless, and green process that can be carried out in small as well as large quantities in any given space. It is known to decrease soil toxicity and enhance plant growth in a soil-contaminated area.

VIII. GENERAL MORPHOLOGY OF EARTHWORM

Earthworms are elongated, narrow, and vermiform in shape. A mature worm measures about 150mm in length and 2.5-5 mm in width. These organisms belong to the Phylum Annelida, Order Haplotaxids, and are usually dark brown to reddish brown in colour due to the presence of porphyrin pigment present in them which helps from harmful UV rays. These organisms exhibit bilateral symmetry and also have metameric segmentation i.e., external segmentation corresponds to internal segmentation of the body. Around 100-150 segments are seen depending on the species of earthworm.

Figure 1: External Morphology

Prostomium and peristomium present, act as mouth and a boring part (to bore into the soil). A thick girdle-like collar is present in the 14, 15,16th segments called clitellum, this has glands that secrete mucus and also help in cocoon formation. The locomotory organ of earthworms is Setae, made from a hard substance called chitin, which helps in the overall movement of the worm. Anus is present at the end, through which excreta is let out.

IX. TYPES OF VERMICOMPOSTING

Vermicomposting can be of two types based on the quantity:

1. **Vermicompost in a Bin:** this method is used in small scales such as home composting, kitchen waste compost production, preparation of manure for the garden, etc.

2. **Vermicompost in a Vermicomposting Pile:** this method is used in large-scale processes, mainly in farming and agriculture.

X. GENERAL VERMICOMPOSTING

Vermicompost is prepared mainly by using organic waste such as kitchen waste, dry leaves, flowers, paper, fruit and vegetable peels, animal excreta, farm waste, animal dung such as cow dung, etc. along with water.

All of these are added in layers along with generous amounts of cow dung and water. It is left to sit for a minimum of 21 days with continuous stirring of the contents in between for uniform decay. After decaying, fresh compost is obtained, this is mixed with earthworms and added to plants as manure.

XI. VERMICOMPOSTING IN LARGE SCALE

Large-scale vermicomposting is done for farming, tea compost, landscaping, rearing of earthworms, or for sale as compost for plants. It is mainly done in two ways: Windrow and Raised bed.

1. **Windrow Method of Composting:** Windrows are typically built on a concrete floor. It could be on top of the soil or in a hole. Windrows are stacked in a straight line and include feedstocks that can reach a height of three feet. It will be necessary to create an earthworm bed with soil, straw, leaves, etc. The entire pile is covered with PVC covering during the composting process to shield it from predators and potential environmental hazards. Compost is made using a windrow technique, which involves piling organic waste, including crop wastes and animal dung, in long rows. Large amounts of compost can be made with this process. Usually, these rows are converted to organic material after composting.

Figure 2: Windrow Composting

2. **Raised Bed:** Axes are used to lift the soil on the ground in this method of farming so that a bed can be made. Anything that gives worms a habitat that is somewhat steady is considered bedding. Over the bedding, the feedstock is spread uniformly to maintain moisture. After the preparation, PVC is laid out over the bed to maintain the moist environment and create a shady place for the multiplication of earthworms.

Figure 3: Raised Bed

XII. VERMIREMEDIATION

The same technique of vermicomposting is used for vermiremediation where suited earthworm species are selected and then mixed with vermicompost left well within the contaminated area. These worms along with certain bacteria help in biodegradation of contaminants present hence detoxifying soil. Vermiremediation mainly includes five steps: ingestion, accumulation, transformation, degradation, and egestion.

1. **Ingestion** is eating the given substrate (organic material) by the earthworm

2. **Accumulation** is the process of an assemblage of ingested material in the gut of the earthworm

3. **Transformation and Degradation** are the processes of metabolic breakdown of accumulated materials by the action of enzymes and microbes on them. The broken-down material is called worm castings or vermicompost which is rich in nutrients such

as phosphorous, calcium, iron, nitrogen, potassium, etc.

Figure 4: *Eisenia Fetida*

In India, certain species of earthworms *Perionyx excavatus, Eisenia fetida, Lumbricusrubellis, and Lampitomauritii*are widely used for vermicomposting and vermiremediation due to their adaptability to Indian soil for better functioning and high survival rate in the environment. After the process of vermiremediation, the leftover compost can be reused as manure for plants and hence is a zero-waste method of removing contaminants from the environment. Hence this method is eco-friendly, affordable, and effective. Current trends in vermiremediation focus on the degradation of heavy metals and plastic-based materials such as bags, sanitary napkins, diapers, boxes, etc which take hundreds of years to completely degrade in nature.

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