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Research Article

Emerging Approaches of Bioremediation: A Comprehensive View

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Abstract

Today, contamination of sites by uncontrolled discharge of pollutants due to rapid industrial growth and anthropogenic activities are causing ecological problems leading to imbalance in nature, is a global concern. In present scenario bioremediation is providing an eco- friendly option for environment betterment. This paper gives an overview of advancement clean-up techniques that have tremendous potential to degrade waste biologically using modified organisms and help in pollution abatement.

Keywords: Discharge, Bioremediation, Modified organisms, Pollution abatement

Introduction

Quality of life on earth depends on the availability of land, air and water. In early times, a great abundance of land and natural resource was present, however changing life style, habits of people, lack of time and negligence in using them not only causing depletion of resources but creates dumping of hazardous waste into the environment like rubber, plastics, agricultural waste, and industrial waste is harmful to living creatures hence disposal is worldwide problem.

The several conventional techniques used for remediation is to dig up polluted soil and remove it to a land fill has serious risks in excavation, handling and transportation of toxic materials. Another ways to treat waste are high temperature incineration, chemical treatment methods, but due to lack of public acceptance and their cost, end products which are formed in turn are again toxic, unable to complete purpose. There is an urgent need to develop new technologies which are cost-effective and eco-friendly. One of the green technologies to treat these hazardous chemicals is bioremediation.

Bioremediation is an increasingly popular alternative to conventional chemical methods for treating waste compounds and media with the possibility to degrade contaminants into less harmful substance. Bioremediation has been used at a number of sites worldwide, including Europe, USA. Unfortunately, the principles, techniques, advantages, and disadvantages of bioremediation are not widely known to those who deal directly with bioremediation proposals, such as site owners and regulators. Many studies on bioremediation have been reported and the scientific literature [1-4] has revealed the progressive emergence of various advances in bioremediation techniques.

Process of Bioremediation

Bioremediation is an effective process that utilizes the metabolic potential of living organisms such as plants, bacteria, and fungi, algae to clean up contaminated environments, to detoxify, degrade or remove environmental pollutants [5-7]. It is very important to understand that this form of waste remediation uses no toxic chemicals, although it may use an organism that can be harmful under certain circumstances. A simple explanation of bioremediation is the use of maggots in wound care control. Wounds that have contamination can have maggots introduced to them. The maggots then eat the contamination, allowing the wound to heal correctly. That is a form of medical bioremediation but there are many other types that are used to control different waste contamination. At sites filled with waste organic material, bacteria, fungi, nematods, and other microorganisms keep on breaking down organic matter to decompose the waste.

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If environment is filled with oil spill, some organisms would die while some would survive. Bioremediation works by providing these organisms with different materials like fertilizer, oxygen and other conditions to survive. This would help to break the organic pollutant at a faster rate and help to clean up oil spill.

Factors affecting bioremediation

- **Bioavailability**: Basically remediation of contaminants depend on the existence of microbial mass having capability to degrade, if microbes are not present in any system they can be added ,cultured and isolated from any condition and have capabilities to survive in extreme conditions with and without oxygen, at sub zero temperature and in desert ,if basic requirement of microbes met.

For degradation it is necessary that bacteria and the contaminants be in contact. This is not easily achieved, as neither the microbes nor contaminants are uniformly spread in the soil. Some bacteria are mobile and exhibit a chemotactic response, sensing the contaminant and moving toward it. Other microbes such as fungi grow in a filamentous form toward the contaminant. It is possible to enhance the mobilization of the contaminant utilizing some surfactants such as sodium dodecyl sulphate (SDS) [9]

Environmental Factors

- **Nutrients:** Bioremediation rely on the growth and activity of microbes irrespective of their numbers and can be stimulated by addition of nutrients (C, H, N, O, P, and S) which allow enzymes to degrade contaminants.
- **Environmental conditions**: Optimal conditions are required to remediate waste include water content and geological structure of soil involve type, particle size, pH permeability, moisture, temperature, amount of available oxygen reported in Table-2 [10]affect degradation of contaminants.

Bioremediation Strategies

Broadly depending on the basis of removal of waste, organism can be used *in-situ* and *ex-situ* conditions.

In-situ bioremediation

In-situ techniques provide treatment of polluted site in place without excavation and transport of contaminants. It is used for soil and ground water with minimum disturbance. (i) **Bioventing** is the most common *in-situ* treatment, requires presence of indigenous organisms capable of degrading the contaminants of interest, as well as nutrients necessary for growth. This is an aerobic process involving air supply for the biodegradation while minimizing volatilization and release of contaminants to the atmosphere. It is used to treat soil contamination by fuels, volatile organic compounds.

- **Biostimulation:** is the in-situ treatment of subsurface

Table1.Some contaminants potentially suitable for bioremediation [8]

Class of contaminants	Specific examples	Potential source
Chlorinated solvents	Perchloroethylene Trichloroethylene	Drycleaner Chemical manufacture
Polychlorinated biphenyls	4- Chlorobiphenyl 4,4-Dichlorobiphenyl	Electrical manufacturig
Chlorinated phenols	Pentachlorophenol	Landfills
BTEX	Toulene, Benzene	Oilprodu ctionPaint manufacture
Polyaromatic hydrocarbons	Naphthalene, Anthracene	Coke plants
Pestcides	Atrazine, Carbofuran 2-4-D	Landfill Timber treatment Pesticide manufacture

Table 2.Environmental conditions required for degradation of contaminants

Parameters	Required conditions	Optimum value
Soil moisture	25-28%	30-90%
Soil pH	5.5-8.8	6.5-8.0
Oxygen content	Aerobic min. air filled pore space10%	10-40%
Nutrient content	N,P	C:N:P=100:10:1
Temperature	15-45	20-30
Contaminants	Not too toxic	Hydrocarbon 5-10% of dry weight of soil
Heavy metals	2000ppm	700ppm
Type of soil	Low clay or silt content	

region by addition of water-based solutions carrying nutrients, electron acceptor to stimulate growth of naturally occurring bacteria to degrade organic contaminants.

- **Biosparging:** is an *in-situ* treatment process designed to treat ground water contamination by injecting air below the water table to increase groundwater oxygen concentrations and enhance the rate of biological degradation of contaminants by indigenous bacteria.
- **Bioaugmentation** It involves the addition of nonindigenous organisms and genetically engineered variants to the contaminated sites, where soil and groundwater are contaminated with chlorinated ethenes, such as tetrachloroethylene and trichloroethylene which are biodegraded by microbes to ethylene and chloride, which are non-toxic. [11]
- **Natural attenuation** is an *in-situ* treatment method that uses natural processes to contain the spread of contamination and reduces the concentration and amount of pollutants at contaminated sites especially hydrophobic contaminants such as high molecular weight PAHs that tend to sorb very tightly to soil particles and by reducing migration rates. Often, communities of adopted degraders mineralize such contaminants quickly after they desorb from soil particles.
- **Phytoremediation** The technique of phytoremediation includes conversion of various heavy metals, organic contaminants from soil and water by plants and transform into less harmful materials with enzyme assisted metabolism.

Ex-situ bioremediation

Ex-situ treatment involves excavation and transportation of contaminated soil at another place.

- **Land farming** is a most adopted technique in which contaminated soil is excavated and sandwiched between concrete layer at top and clean soil at bottom. By maintaining pH, concentration of oxygen and nutrients required to stimulate indigenous biodegradative microorganisms which facilitate their aerobic degradation of contaminants. In general, the practice is limited to the treatment of superficial 10–35 cm of soil. It has received worldwide attention as a disposal alternative due to reduce monitoring and maintenance cost**.**
- **Composting** is a technique that involves degradation of waste by microbial mass into nutrient rich manure by releasing heat increases metabolic activity in compost.
- **Biopiles** are used for treatment of surface contamination with petroleum hydrocarbons. It is a hybrid of land farming and composting in which especially engineered aerated composted piles are constructed having aeration, nutrient and leachate collection system. Biopiles provide a favorable environment for indigenous aerobic and anaerobic microorganisms.
- **Bioreactor**s most preferred *ex- situ* treatment of contaminated solid material (soil, sediment, and sludge) or water used for petrochemicals, explosive, solvents pesticides through an engineered containment system. Slurry contains 10-40% solid material added to the reactor, and parameters such as pH and temperature are controlled to optimize biological processes. A slurry bioreactor is a containment vessel 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.

Recent Approaches in Bioremediation

Advances in biotechnological tools and their application in biological system are providing new ways to bioremediation.

- **Designer Microbes Approach** genetically engineered organisms are generated by recombinant DNA technology in which genetic material is altered to generate character specific microbial strain have capabilities to degrade contaminant at the polluted sites. Various biosensors have been designed to evaluate heavy metal concentrations like mercury (Hg), cadmium (Cd), nickel (Ni), copper (Cu) and arsenic (As) [14-15].
- **Application of Nano-Biotechnology** This innovative technique is a promising tool to construct or manipulate nano-objects. A nanoparticle enhancing microbial activity is employed to remove toxic pollutants is called nanobioremediation. Nanotechnology through biotechnology remediates organic contaminants, heavy metals. Deinococcus radiodurans, a radioactive-resistant organism, has the ability to withstand radiation well beyond the naturally occurring levels, thus its application in radioactive waste clean-up initiatives funded by US Department of Energy (DOE) [16]. Nanoscale modified biopolymers are genetically engineered variants. They are synthesized by manipulating culture conditions pH, temperature according to desired requirement of environment to remove toxic pollutant.
- **Application of Genomics** This bioremediation technique involves genetically designed microbe sensitivity towards waste material in agriculture fields. Lack of skilled persons, high cost input and competiveness create hurdles.
- **Application of Biosurfactants** Microbial compounds, which exhibit particularly high surface and emulsifying activity, are classified as biosurfactants .They are surface-active substances synthesized by living cells.

Use of biosurfactants will reduce the hydrophobicity of contaminants and make it readily available to the biological system for their remediation.

- **Role of Oxygen Releasing Compounds** ORC is applied to enhance aerobic remediation rate in total petroleum hydrocarbons.
- **Microbes Assisted Phytoremediation** It is an application of bioremediation in transgenic plants, organisms regulated by biotechnology to remove contaminants.
- **Application of Bioinformatics** It gives pre-information of cellular processes associated with bioremediation. Bioinformatics is helpful in identifying and analyzing various components of cells such as gene, protein functions, interactions, and metabolic regulatory pathways. It facilitates to understand the cellular mechanism, to treat and control microbial cell.

Conclusion

Bioremediation is a promising efficient, cost effective tool to cleanup environment. A single technique is unable to remediate contaminated site full of various types of wastes. In future a group of microbes called microbial consortia or genetically modified organism can be developed to remove pollutants. There are various possibilities of successful research if hurdles will be removed.

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