Microbial Bioremediation: An Advanced Approach for Waste Management

Rachna Chaturvedi¹*, Jyoti Prakash¹, Garima Awasthi¹, Dr. Rachna Chaturvedi*¹

1. Amity Institute of Biotechnology, Amity University Uttar Pradesh, Lucknow, U.P., India
*Corresponding author

Abstract

Environmental contamination is increasing day by day because of increase in population, industrialization and urbanization. Industrial waste has become a major threat causing the environmental pollution, affecting the water, air and soil. Waste disposal is a major problem faced by industries, due to generation of high volume of effluent and with limited space for land based treatment and disposal. The constant use of these effluents is having harmful effects on the crops when used for irrigation. As a result, an elevated amount of various elements get deposited in the soil and make them contaminated. Since this contaminated soil reduces both the crop production simultaneously the soil properties. Bioremediation is simple, low-cost, environment friendly technology that is powered by microbial community. Bioremediation is the technology that involves the role of microbes through microbial metabolism, which undergo physical and chemical reactions to remove pollutants. These microbes including aerobic, anaerobic bacteria, fungi, yeast and algae and are involved in degradation of undesirable compounds into less harmful products. Rapid advances in the last few years have helped us in the understanding of process of bioremediation. Bioremediation is an attractive and successful globally accepted technique for maintaining the safe and uncontaminated atmosphere. Current review is focused on the role of microbes in remediation of waste.

Keywords: Bioremediation, Microbes, Ex situ, In situ, Environmental factors

1. Introduction

Industrialization, urbanization, as well overpopulation is the major threat to our ecosystem. Strengthening of agriculture and manufacturing industries has resulted in increased release of a wide range of xenobiotic compounds to the surroundings. Disposal of huge amount of hazardous waste has led to insufficiency of clean water and instability of soil, thus preventing crop production [1].

Waste can be categorized into solid, liquid or gas, which may affect the health either directly or cause major harm to natural resources via soil, water and air. However, wastes have become trouble-some and must be disposed-off in natural resources. In the past nature was responsible for disposal of such wastes due to the less population of men and abundant capacity of natural resources. Now it is vice-versa. Hence for the welfare of public cleanliness, public health and countrywide wealth, the wastes, especially the community sewage, should be disposed-off in a hygienic and harmless way of lowering costs. For this purpose particular consideration has to be paid to acquire secondary use or recovery or adaptation of the waste into useful products (which can be well utilized. Bioremediation is one of the most important process which can be used for the removal of pollutants from contaminated soil and water, as they get metabolized by microorganisms i.e. yeast, fungi or bacteria [2]. It is an option that offers the possibility to destroy or render harmless contaminants using natural biological activity such as microorganisms or their enzymes so that to return the environment to its original condition [3]. Microbial metabolism is well known mechanism for degradation of complex compounds [4, 5]. Recently these advancements are proved successful via the addition of suitable microbial strains to the medium to increase the ability to break down contaminants. Microorganisms used to carry out the bioremediation are known as bioremediators [6]. Bioremediation is comparatively simple, low-cost techniques, which normally have a high public recognition and can often be carried out on site. It depends on promoting the growth of specific microorganisms that are indigenous to the polluted sites and able to perform desired activities [7]. Such microbial consortia can be obtained in several ways like by addition of nutrients, by adding terminal electron acceptor or by controlling moisture and temperature conditions [8, 7, 9]. In
the process of bioremediation microorganisms use the contaminants as nutrient or energy sources \[8, 7, 10\]. Pollution in soil and water is increased due to population explosion in the world as the increase in population will create pressure on our natural resources i.e. air, water and land resources, also deterioration of soil occurred due to use of chemicals which are released in huge amount due the rapid expansion of industries, agricultural practices, health care, vehicles, etc \[11\]. Quality of life is decreased with all these new unfavorable developments of the environment in which we live. In nature there are various microorganisms those constantly break down organic compounds. Several researchers have described a variety of application of microorganism in the bioremediation of oil pollution with hopeful results \[12, 21\]. The field application foci are co metabolic techniques, biogeochemical measurement techniques, and modeling of attenuation and ecological fate \[22\]. Some heavy metals such as cadmium and lead are not readily absorbed or captured by organisms may be resistant against bioremediation \[23\]. The incorporation of metals such as mercury into the food chain may make things worse due to bioaccumulation these metals by organisms can reduce pollution of metal. Bioremediation technique can also be used for removal of heavy metals from wastes, Pseudomonas spp. is a good bio sorbent and has a great potential to remove heavy metals from waste water, effluent and soil \[24\]. Bioremediation is not only a solution but a natural procedure due to normal capability of microorganisms to degrade organic compounds. Bioremediation is not a panacea but rather a natural process alternative to some of the options as burning, catalytic devastation, the use of adsorbents, and the physical elimination which help in reducing the pollutants. The expenditure of incinerating pollutants is at least ten times that of in situ bioremediation. Bioremediation can be successful by integrating good use of accepted or modified microbial capabilities with suitable engineering designs. Successful application of bioremediation techniques must address both the mixed nature of many contaminated waste sites and the complication of using living organisms. Scientists have to put their efforts to search for organisms with better biodegradation kinetics for a variety of contaminants within broad environmental habitats.

2. Principles and Fundamentals of Bioremediation

Environmental biotechnology is not a new field; composting and wastewater treatments are well-known examples of old environmental biotechnologies. Bioremediation is the process in which living organisms, primarily microorganisms are used to degrade the environmental contaminants into less toxic or risk free State under restricted conditions. \[25\]. The effectiveness of bioremediation depends, when microbes enzymatically hit the contaminants and convert them to safe and sound products \[23\]. The bioremediation techniques mean to speed up the naturally occurring biodegradation process by optimizing the environmental conditions required for microbial growth and activity, its application often involves the manipulation of environmental parameters to allow microbial growth and degradation to proceed at a faster rate. \[26\]. The microorganisms may be native to a polluted area or they may be isolated from a different place and brought to the contaminated site. Most bioremediation systems are run under aerobic circumstances, but running a system under anaerobic conditions may permit microbial organisms to degrade unmanageable molecules \[27\]. Pollutant compounds are changed by living organisms through metabolic reactions that take place as a part of their processes. The rates of clean-up is random depending on type of contaminants, as some contaminants, such as chlorinated organic or high aromatic hydrocarbons, are challenging to microbial hit hence they are degraded either less or not at all. This technology offers the prospective to care for polluted soil and ground waters on site devoid of the need for dig, requires comparatively slight energy input, and conserve the soil organization \[28-30\]. Perhaps the most striking characteristic of bioremediation is its reduced impact on accepted ecosystems, which should be well acknowledged by the public \[31\].

3. Factors of Bioremediation

Main factors which are accountable for managing and optimization of bioremediation processes depends on microbes (biomass concentration, population diversity, enzyme activities), competent of degrading the pollutants, the contaminants available for the microbes and the environmental factors as type of soil, temperature, pH, the presence of oxygen or other electron acceptors, and nutrients (Table 1). Therefore,
conditions that help microbial growth and activity in soil will also generally encourage metabolic degradation of pollutants [28].

Table 1 Factors effecting bioremediation

<table>
<thead>
<tr>
<th>S.No</th>
<th>Factors</th>
<th>Types</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Microbial population</td>
<td>Aerobic or Anaerobic</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Growth Of Microbes</td>
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<tr>
<td></td>
<td></td>
<td>Mutation and horizontal gene transfer</td>
</tr>
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<td></td>
<td></td>
<td>Enzyme induction</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Enrichment of the capable microbial populations</td>
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<tr>
<td></td>
<td></td>
<td>Production of toxic metabolites</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Lack of nutrients</td>
</tr>
<tr>
<td>2</td>
<td>Contaminants</td>
<td>Too low concentration of contaminants</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Chemical structure of contaminants</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Toxicity of contaminants</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Solubility of contaminants</td>
</tr>
<tr>
<td>3</td>
<td>Biological aerobic vs anaerobic process</td>
<td>Oxidation/reduction potential</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Availability of electron acceptors</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Microbial population present in the site</td>
</tr>
<tr>
<td>4</td>
<td>Growth substrate vs co-metabolism</td>
<td>Type of contaminants</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Concentration</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Alternate carbon source present</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Microbial interaction (competition, succession, and predation)</td>
</tr>
<tr>
<td>5</td>
<td>Physico-chemical bioavailability of pollutants</td>
<td>Equilibrium sorption</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Irreversible sorption</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Incorporation into humic matters</td>
</tr>
<tr>
<td>6</td>
<td>Environmental Factors</td>
<td>Depletion of preferential substrates</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Lack of nutrients</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Inhibitory environmental conditions</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Electron acceptor/donor</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Oxygen content, pH, 5.5 – 8.8</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Type of nutrients C,N,P</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Soil type Low clay or silt content</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Temperature 15°C – 45°C</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Moisture content 45 – 85 %, 25–28% of water holding capacity</td>
</tr>
<tr>
<td>7</td>
<td>Mass transfer limitations</td>
<td>Oxygen diffusion and solubility</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Diffusion of nutrients</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Solubility/miscibility in/with water</td>
</tr>
</tbody>
</table>

The nutrients as nitrogen, phosphorous, and carbon are the essentials of life and permit microbes to generate the necessary enzymes to break down the contaminants (Table 1). However, it has also been discovered that in addition much amounts of nitrogen in soil cause microbial inhibition. It is evidenced that “petroleum-
contaminated soil with nitrogen is competent of increasing growth rate, decrease the lag phase, help to keep up microbial populations at high action levels, and add to the rate of hydrocarbon degradation" [32]. Addition of phosphorus has benefits equal to that of nitrogen, but also results in identical restrictions when applied in overload [33]. Growth and activity of microbes are affected by, temperature, pH and moisture. Although some of microbes have been also isolated in extreme environment, but most of them need to grow over a narrow range of most favorable conditions. If the soil is acidic it can be optimized by addition of lime. Temperature affects biochemical reactions rates, as the rates of many of them double for each 10 °C rise in temperature [34]. Most bacteria found in soil, as well as many bacteria that degrade petroleum hydrocarbons, are mesophilic which have an best possible temperature ranging from 25°C to 45°C [34]. Higher temperature usually enhances the bioremediation rates due to increased surface activity and kinetic energy of the solute [35]. Accessible water is necessary for all the microbes hence; irrigation is required for the optimum moisture level. Soil moisture content “between 45 and 85 percent of the water-holding capacity of the soil is optimal for petroleum hydrocarbon degradation” [36]. Presence of oxygen will decide whether the system is aerobic or anaerobic. Petroleum hydrocarbons are without difficulty degraded under aerobic conditions, by losing electrons and is oxidized while oxygen gains electrons and are reduced, resultant is in formation of carbon dioxide and water [34]. While anaerobic situation are appropriate for chlorurate compounds. Soil structure is responsible for efficient delivery of air, water, and nutrients for the growth of microorganism. Gypsum or organic matter may be useful for perfection of soil structure while low soil permeability is not suitable for in situ clean-up techniques because it can block movement of water, nutrients, and oxygen. Nevertheless, under situation of low moisture and nutrient contents, microbial metabolism becomes compromised, and triazines and other xenobiotic compound persistence may increase as a result [37]

4. Types of microbes effecting bioremediation processes
Microbe like bacteria, fungi, yeast and algae can be used for bioremediation, they can grow and adapt some extreme conditions like chilled temperatures, extreme heat, desert conditions, in water, aerobic and anaerobic conditions, with the occurrence of unsafe compounds or on any type of waste. The main necessities for the growth of microbes are an energy source and a carbon source [23]. Due to this flexibility of microbes and other biological agents, they can be utilized for remediation of waste. Conventional microbes, either indigenous or extraneous are the chief agents used for bioremediation [38]. The microbes may be different, depending on the chemical character of the contaminants and should be selected carefully due to their survival within a restricted range of chemical contaminants [38-39]. Since several types of pollutants are to be encountered in a contaminated site, diverse types of microorganisms are expected to be required for efficient mediation [40]. The first patent for a biological remediation agent was registered in 1974, being a strain of Pseudomonas putida [38] that was able to degrade petroleum fuel as in 1991, approximately seventy microbial genera were reported to degrade petroleum compounds [41] and around the same number has been added in the successive two decades [36].

Some major groups of microbes

Aerobic Bacteria: Some of the aerobic bacteria acknowledged for their abilities for degradation are Alcaligenes, Pseudomonas, Rhodococcus, Sphingomonas, and Mycobacterium. These microbes have often been reported for the degradation of pesticides and hydrocarbons; contain both alkanes and polyromatic compounds. Most of these bacteria consume the pollutant as the sole source of carbon and energy. Methyloptrophs are the aerobic bacteria that grow exploiting methane for carbon and energy. The initial enzyme in the pathway for aerobic degradation, methane monoxygenase, has a broad substrate range and is active against a wide range of compounds, including the chlorinated aliphatic trichloroethylene and 1, 2-dichloroethane

Anaerobic Bacteria: Anaerobic bacteria are not as frequently used as aerobic bacteria. Mostly anaerobic bacteria used for remediation of polychlorinated biphenyls (PCBs) in river sediments, chloroform and dechlorinating the solvent trichloroethylene (TCE)
**Lignin lytic fungi.** Fungi for example white rot fungus *Phanaerochaete chrysosporium* have the ability to degrade an extremely different variety of constant and lethal environmental contaminants by means of substrates straw saw dust, or corn cobs.

**Algae:** Few study has also reported that various researcher also worked on various types of algae which are capable to accumulate heavy metals present in the fresh and marine water bodies. The metals also have hazardous impacts on aquatic environment. The macrophytes have also been found as a potential source for accumulation of heavy metals from waste water bodies.[12-14]

**Table: 2 Microbes responsible for utilization of Metals and Xenobiotics**

<table>
<thead>
<tr>
<th>Microbes</th>
<th>Contaminants</th>
<th>References</th>
</tr>
</thead>
<tbody>
<tr>
<td><em>Bacillus spp.</em> <em>Pseudomonas aeruginosa</em></td>
<td>Cu, Zn, Cr, Fe</td>
<td>[37,38, 44]</td>
</tr>
<tr>
<td>Zooglea spp.</td>
<td>U, Cu, Ni</td>
<td>39,40</td>
</tr>
<tr>
<td><em>Citrobacter spp.</em>, utilizes</td>
<td>Co, Ni, Cd</td>
<td>39,40</td>
</tr>
<tr>
<td><em>Chlorella vulgaris</em></td>
<td>Cd, U, Pb, Au, Cu, Ni, U, Pb, Hg, Zn</td>
<td>38</td>
</tr>
<tr>
<td><em>Aspergillus niger</em></td>
<td>Cd, Zn, Ag, Th,</td>
<td>38,41</td>
</tr>
<tr>
<td><em>Pleurotus ostreatus</em></td>
<td>U Cd, Cu, Zn</td>
<td>38,45,46</td>
</tr>
<tr>
<td><em>Rhizopus arrhizus</em></td>
<td>Ag, Hg, P, Cd, Pb, Ca</td>
<td>38,45,46</td>
</tr>
<tr>
<td><em>Stereum hirsutum</em></td>
<td>Cd, Co, Cu, Ni</td>
<td>38,47,48</td>
</tr>
<tr>
<td><em>Phormidium valderium and Ganoderma applantus</em></td>
<td>Cd, Pb Cu, Hg, Pb Cd, Pb Cu, Hg, Pb</td>
<td>46,47,</td>
</tr>
<tr>
<td><em>Volvariella volvacea</em> utilizes</td>
<td>Zn, Pb, Cu</td>
<td>47,48,</td>
</tr>
<tr>
<td><em>Pseudomonas spp.</em>, <em>Alcaligens spp.</em>, <em>Arthrobacter spp</em></td>
<td>Benzene, anthracene, hydrocarbons, PCBs Halogenated hydrocarbons, linear alkyl benzene sulfonates, polycyclic aromatics, PCBs Benzene, hydrocarbons, pentachlorophenol, phenoxyacetate, polycyclic aromatic, long chain alkanes, phenol, cresol</td>
<td>49-50</td>
</tr>
<tr>
<td><em>Bacillus spp</em> <em>Corynebacterium spp</em>, <em>Flavobacterium spp</em>, <em>Azotobacter spp</em>, <em>Rhodococcus spp Mycobacterium spp</em>, <em>Nocardia spp, Methosinus spp</em>, <em>Methanogens and Xanthomonas</em></td>
<td>Halogenated hydrocarbons, phenoxyacetates Aromatics Naphthalene, biphenyl, branched hydrocarbons, benzene, cycloparaffins, hydrocarbons, polycyclic hydrocarbons, halogenated hydrocarbon diazoin PCBs, formaldehyde, polycyclic aromatics, biphenyls</td>
<td>50,52,53,54,55</td>
</tr>
</tbody>
</table>

5. **Bioremediation strategies**

In-Situ Bioremediation

In situ bioremediation means there is no need to excavate contaminated soils or water in order to attain remediation and it is supposed to be the application of natural treatment to the cleanup of harmful chemicals present in the subsurface without disturbing natural surroundings of the site. This action is limited by the deepness of the soil that can be efficiently treated. In situ bioremediation involves encouragement of physically occurring bacteria accountable for degradation of organic contaminants by supplying oxygen and
nutrients via circulating aqueous solutions through contaminated soils. This procedure can be used for soil and groundwater frequently, includes situation involved in infiltration of water containing nutrients and oxygen or other electron acceptors for groundwater handling [23]. It is a highly developed method to cleaning contaminated environments as it uses safe and sound microbes to degrade the chemicals as well as it is cheaper, hence these techniques are normally the most attractive options due to lower cost and fewer disturbances. Microorganisms having chemo tactic abilities can shift into an area containing contaminants.

So by enhancing the cells’ chemo tactic abilities, in situ bioremediation will be transformed into a safer technique in degrading detrimental compounds. Hence Chemo taxis are important to the study of in situ bioremediation. The optimization and control of microbial transformations of organic contaminants need the addition of many technical and manufacturing disciplines.

Insitu Bioremediation may be Intrinsic means residents or logically occurring microbes are stimulated by feeding them nutrients and oxygen to increase their metabolic activity and may be engineered in which the growth and degradative activity of microbes is increased by using engineered system that supply nutrients, electron accepters and growth stimulating materials when site conditions are not suitable.

**Bio attenuation**
This is the process of monitoring the natural process of degradation to ensure decrease in concentration of contaminants at the site.

**Biosparging**
This procedure involves the creation of air under pressure under the water label to boost oxygen concentrations of groundwater and recover the rate of biological degradation of contaminated region by naturally occurring bacteria. The fitting of small-diameter air inoculation points is simple and of low cost, allows substantial flexibility in the design and structure of the arrangement. It is accountable for increases in the addition of the saturated region and thereby increases the contact between soil and groundwater. This is most well-organized and noninvasive technique having bio degradative abilities of native microorganisms with occurrence of metals and inorganic compounds [62, 63, 6, 27].

**Bioventing**
This is a potentially a new technology that is stimulating the normal *in-situ* bioremediation of any aerobically degradable compounds contained by the soil by providing oxygen to accessible soil microbes. In compare to soil-vapor extraction (SVE), bioventing uses little air-flow rates to provide only enough oxygen to keep microbial activity. Bioremediation of adsorbed fuel residues and unsteady compounds is completed as fumes move slowly from beginning to end of biologically dynamic soil [64]. This technique combines an increased oxygen supply with extraction of vapour. A vacuum is created at some depth in the contaminated soil which does air downward into the soil from holes drilled in the region of the mark and sweeps out any unpredictable organic compounds. The progress and purpose of bioventing for *in situ* elimination of petroleum from soil have to remediate about 800 kg of hydrocarbons by venting and approximately 572 kg by biodegradation [65].

**Bio augmentation**
This is the introduction of a compilation of preselected organisms, normal microbial strains or a genetically engineered alternative to treat contaminated soil or water raising the rate or amount, or both of bioremediation. It is in general used in community wastewater handling. In this process the achievement of bioremediation is chiefly dependent on the competition potential of the introduced species and the bioavailability of the xenobiotic compounds [28]. Bioavailability here refers to the attainment and successive transformation of the compound [166] and is closely related to its chemical properties, as well as to a broad range of soil physical and chemical parameters. The chosen microorganisms have to be carefully matched to the waste contamination present as well as the metabolites formed. At sites where soil and groundwater are impure with chlorinated ethenes, such as tetrachloroethylene and trichloroethylene, bio augmentation is used to make sure that the *in situ* microorganisms are capable of total degradation these contaminants to ethylene and chloride, which are non-toxic [63]. Different marketable cultures were reported to degrade petroleum hydrocarbons [67,73]. In study by Ruberto et al. (2003) [72] on the bioremediation of a hydrocarbon polluted
Antarctic soil recognized a 75% removal of the hydrocarbon when the polluted soil was bio augmented with a psychrotolerant strain (B-2-2). The two fungal species were capable to get rid of PAHs from the polluted soil where the concentrations of phenanthrene, anthracene, fluoranthene and pyrene decreased up to 66% after a 10-week management. Two white rot fungal species, *Irpex lacteus* and *Pleurotus ostreatus*, were used as inoculums for bioremediation of petroleum hydrocarbon-contaminated soil from a manufactured-gas-plant-area. The most familiar quality of valuable seed organisms is their capacity to degrade most petroleum components, feasibility during storage, genetic strength, and fast growth in successive storage, a high stage of enzymatic activity and development in the surroundings, competence to resist with native microorganisms, no pathogenicity and incapability to create lethal metabolites. The potential of a bacterial grouping for remediation of Gulf and Bombay High crude oil was reported by Chhatre et al. (1996). According to their view some members of the group were competent of to degrade enzymatically, 70% of the crude oil, while others resourcefully degraded crude oil by manufacture of bio surfactant and rhamnolipid.

**Bio stimulation**

This method involves the encouragement of original microorganisms to degrade the contaminant. It characteristically involves the addition nutrients (e.g., carbon and nitrogen sources, O₂), acid or bases for pH optimization, or water or exact substrates to encourage precise enzymes. It is an useful bioremediation policy although it may have reduced reproducibility and is dependent on the characteristics of microbial populations. Hence nitrogen and phosphorus containing substrates has been added to stimulate the unusual microbial populations. The 39.5% decline in total hydrocarbon content of an aged contamination of crude oil contaminated soil is reported while studying the hydrocarbon-degrading bacterial population in laboratory soil columns during a 72-day bio stimulation management with a mineral nutrient and surfactant solution. The problem of nutrient restrictions has been defeated by applying fertilizers.

**Ex-Situ Bioremediation**

**Composting**

Composting is a solid-phase treatment by which organic wastes are degraded by microorganisms, characteristically at high temperatures ranging from 55°C to 65°C. The increased temperatures are the consequences from heat formed by microorganisms throughout the degradation of the organic material in the waste. A method that treats soils in above ground conduct areas prepared with collection systems to stop any contaminant from avoiding the treatment. Windrow composting has been established as polluted soils are excavated and screened to remove huge rocks and debris. This method involves incorporation of polluted supplies with compost containing bioremediation microbes and this blend incubates under aerobic and temperate situation, resulting compost can be utilized as a soil augmentation or be located in a clean landfill. Moisture, heat, nutrients, or oxygen have to be restricted to enhance bioremediation for the end of this conduct. This process is fairly simple to work and keep up but engage a better space and cleanups is time taking than with slurry-phase processes and also it is more expensive than land farming, but more fast.

**Land farming**

The purpose of agricultural tilling and soil modification techniques to support the development of bioremediation microorganisms in a polluted region. It has been used fruitfully to get rid of enormous petroleum spills in soil. Polluted soils are excavated and extend on a cushion with a built-in arrangement to collect any impure liquids that leak out of pollutant flooded soil. The soils are occasionally crooked over to mix together air into the waste while moisture and nutrients are controlled to increase bioremediation. It is cost efficient, simple, economical, self-heating, surface application, aerobic process. This method includes the use of organic materials to natural soils followed by irrigation and ordinary tilling to raise aeration. The region to be treated is lined & dammed to keep any contaminants that pour out. Rate of degradation depends on microbial population, level of contamination and soil type e.g. ½ lives for degradation of diesel fuel & heavy oils is 54 day with this type of system.
Bio piling

Bio pile conduct is a full-scale capability in which excavated soils are mixed with soil amendments, located on a handling region, and bio remediated using necessary exposure to air. Contaminated soil is piled in heaps surrounded by a ruled region and soil lots can be located in enclosures to control overflow, evaporation and volatilization, and to encourage solar heating. Aeration is provided by pulling air through the pile with a vacuum push and maintaining moisture and nutrient levels to exploit bioremediation. Volatile contaminants are without complication insufficient since they are typically fraction of the air flow being pulled through the pile. If volatile organic compounds in the soil volatilize into the air flow, the air exit the soil may be treated to eliminate or destroy the VOCs before they are discharged into the environment. Treatment time is characteristically 3 to 6 months [80]. An electron acceptor is necessary for breakdown of hydrocarbons in form of oxygen, nitrate acid sulfate. Moisture levels ranges from 20% to 80% of saturation normally allow appropriate bioremediation in soils. Temperature must be 35° C for best performance pH should be in range of 7.0 to 7.5

Bioreactors

Bioreactors are normally used to eliminate toxic pollutants from solid waste and soil in a huge tank containing organisms or enzymes. Soil is extracted from a polluted site can be treated as bioreactors of a variety of designs with restricted parameters as temperature, pH, mixing, O2 supply. Bioreactors are Slurry reactors or aqueous reactors which are used for ex situ treatment of contaminated soil and water pumped up from a contaminated column, involved in rapid degradation kinetic, optimizing environmental parameters, enhances mass transfer with effective use of inoculants and surfactant applied for toxic concentrations of contaminants [81].

Bioremediation in reactors involves the dealing out of polluted solid material (soil, sediment, sludge) or water through an engineered containment arrangement. A slurry bioreactor may be defined as a containment container and equipment used to produce a three-phase (solid, liquid, and gas) combined state to raise the bioremediation rate of soil leap and water-soluble pollutants as water slurry of the contaminated soil and biomass.

6. Advantages of Bioremediation

This procedure have a lot of advantages as it does not involve excavation of the contaminated soil and hence proves to be cost effective, less expensive than other technologies that are used for cleanup of hazardous waste. There is insignificant site disturbance, so the amount of dirt created is a less significant and synchronized handling of soil and groundwater is possible.

It is a conventional process, takes a lesser time, high-class sufficient waste treatment procedure for polluted material such as soil, and is therefore supposed to be an appropriate waste treatment process. Microbes competent to degrade the contaminant increase in numbers in presence of contaminant and after degradation, the biodegradative population declines. The residues after treatment are normally risk-free products and comprise carbon dioxide, water, and cell biomass. Theoretically, bioremediation is helpful for the total damage of a broad series of contaminants which are lawfully measured to be unsafe and these can be changed to safe products. Bioremediation also requires a very a smaller quantity of effort and can frequently be passed out on site, constantly with no chief disturbance of general actions. As a replacement for transferring contaminants from one environmental medium to a different, for example, from land to water or air, the total damage of target pollutants by means of bioremediation is promising. This technique also eliminates the call for to transfer quantities of waste off site and the probable terror to human health and the environment that can happen for the duration of transport of contaminants. The nutrients added to create microbes grow are fertilizers normally used on lawns and gardens hence not using any hazardous chemicals. Bioremediation changes the damaging chemicals harmless products so the harmful chemicals are completely destroyed.
Bioremediation is not doing well only for the degradation of pollutants but it can also be used to clean surplus substances from air, soil, water and raw materials forms of industrial waste.

7. Disadvantages of Bioremediation

Bioremediation, although measured an advantage in the middle of present day environmental situations, it poses some disadvantages, as it is considered challenging because, while additives are added to increase the performance of one particular microorganism, it may be troublemaking to other organisms inhabiting in similar surroundings when done in situ [23]. Microorganisms act well only when the waste materials present permit them to produce nutrients and energy for their growth. The capability of degradation is reduced in unfavorable; in such cases the use of genetically engineered microorganisms is required, even though motivation of native microorganisms is favored. Even if genetically modified microorganisms are released into the surroundings after a definite point of time it is difficult to remove them. Bioremediation is limited to those compounds that are biodegradable, not all compounds are susceptible to rapid and complete degradation. An additional difficulty concerning the use of in situ and ex situ processes is that it is causing more harm than the actual pollution itself as the products of biodegradation may be additional persistent or lethal than the parent compound and also imperfect to those compounds that are eco-friendly.

8. Conclusion and future strategies

Rapid industrialization and technology development have adverse side effects like soil contamination and degrading soil health. Due to the complexity involved in the conventional methods for remediation of soil, the use of microbes has arisen as a time-saver for bioremediation. Bioremediation provides a technique for cleaning up pollution by enhancing the natural biodegradation processes. In ex situ use of land farming and bio piles also require monitoring and containing volatilization of contaminants. However, they must have need a large amount of land and, similar to in situ bioremediation, complete degradation is difficult to achieve, and evaporation of volatile components is a concern. [82-83] Important site factors necessary for the best accomplishment are occurrence of metabolically capable microbes, appropriate environmental growth conditions, and proper levels of nutrients and contaminants. So by developing an understanding of microbial communities and their response to the natural environment and pollutants, expanding the knowledge of the genetics of the microbes to increase capabilities to degrade pollutants, conducting field trials of new bioremediation techniques which are cost effective, and dedicating sites which are set aside for long term research purpose, these opportunities offer potential for significant advances. There is no recognized sense of evaluating performance and standard endpoint for bioremediation treatments. With this in view, though many engineered processes for applying bioremediation have been developed but the cheap treatment of such sites has remained an indefinable goal [84]. There is no doubt that bioremediation is in the process of paving a way to greener pastures. Its advantages generally outweigh the disadvantages, which is evident by the number of sites that choose to use this technology and its increasing popularity. Once again thanks to the bioremediation technology to clean up the polluted environment and therefore may be used as management tool.

However, bioremediation technology has limitations; several microorganisms cannot break toxic metals into harmless metabolites, and these have inhibitory effects on microbial activity. Modification in the outer membrane proteins of bacteria with potential bioremediation properties for improving metal binding abilities is the likely way to enhance their capacity for biotransformation of toxic metals. Additional investigations continue to evaluate conditions for thriving introduction of exogenic and genetically engineered microbes into a contaminated environment, and to interpret the accomplishment in the laboratory to achieve in the field [85]. Future studies should focus on the factors involved in improving in situ bioremediation strategies using genetically engineered microorganisms (GEM) and also the applicability and adaptability of these GEMs in all the possible adverse/stress conditions and multiple-heavy-metal-polluted conditions. The reluctance among the public to accept GEM for bioremediation also needs to be considered in future studies, and they must proved non-toxic to the environment. More research is required to expand the bioremediation technologies that are suitable for sites with mixtures of contaminants that are not consistently dispersed in the environment.
9. References:


Prakash, J., and Awasthi, G., Accumulation of Heavy Metals in Different Water Bodies by Biological Source Algae, Advances in Life Sciences. 2013, 2 (1) 10-14.


Bioremediation can be a viable mechanism for treating soils contaminated with petroleum hydrocarbons. Bioremediation strategies range from encouraging natural biodegradation processes (biostimulation), to supplementing the existing system with microorganisms able to degrade the contamination (bioaugmentation), to monitoring and verifying natural processes (natural attenuation). 4.1 Introduction. Bioremediation refers to the use of microorganisms to eliminate or reduce the concentrations of hazardous wastes at a contaminated site (Boopathy, 2000; de Lorenzo, 2008). One important characteristic of bioremediation is that it is carried out in nonsterile open environments comprising of a variety of microorganisms (Huang et al., 2013; Sivakumar et al., 2012).