Chapter

Bioremediation Techniques for Polluted Environment: Concept, Advantages, Limitations, and Prospects

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Abstract

Environmental pollution has been rising in the past few decades due to increased anthropogenic activities. Bioremediation is an attractive and successful cleaning technique to remove toxic waste from polluted environment. Bioremediation is highly involved in degradation, eradication, immobilization, or detoxification diverse chemical wastes and physical hazardous materials from the surrounding through the all-inclusive and action of microorganisms. The main principle is degrading and converting pollutants to less toxic forms. Bioremediation can be carried out ex-situ and in-situ, depending on several factors, which include but not limited to cost, site characteristics, type, and concentration of pollutants. Hence, appropriate bioremediation technique is selected. Additionally, the major methodologies to develop bioremediation are biostimulation, bioaugmentation, bioventing, biopiles, and bioattenuation provided the environmental factors that decide the completion of bioremediation. Bioremediation is the most effective, economical, eco-friendly management tool to manage the polluted environment. All bioremediation techniques have its own advantage and disadvantage because it has its own specific applications.

Keywords: bioremediation, environment, pollutants soil, ground water, waste-water, applications, limitations

1. Introduction

Bioremediation and natural reduction are also seen as a solution for emerging contaminant problems; microbes are very helpful to remediate the contaminated environment. Number of microbes including aerobic, anaerobic bacteria and fungi are involved in bioremediation process. Bioremediation is highly involved in degradation, eradication, immobilization, or detoxification diverse chemical wastes and physical hazardous materials from the surrounding through the all-inclusive and action of microorganisms. The main principle is degrading and converting pollutants to less toxic forms. There are two types of factors these are biotic and abiotic conditions are determine rate of degradation. Currently, different methods and strategies are applied for bioremediation process.

2. Environmental pollution

Environmental pollution has been on the rise in the past few decades due to increased human activities such as population explosion, unsafe agricultural practices, unplanned urbanization, deforestation, rapid industrialization and non-judicious use of energy reservoirs and other anthropogenic activities. Among the pollutants that are of environmental and public health concerns due to their toxicities are: chemical fertilizer, heavy metals, nuclear wastes, pesticides, herbicides, insecticides greenhouse gases, and hydrocarbons. Thousands of hazardous waste sites have been identified and estimated is that more will be identified in the coming decades. Release of pollutants into the environment comes from illegal dumping by chemical companies and industries. Many of the techniques utilized for site clean-up in the past, such as digging up the contaminated soil and hauling it away to be land filled or incinerated have been prohibitively expensive and do not provide permanent solution. More recent techniques such as vapor extraction and soil venting are cost effective but incomplete solution.

2.1 Definition of bioremediation

Bioremediation is a process where biological organisms are used to remove or neutralize an environmental pollutant by metabolic process. The "biological" organisms include microscopic organisms, such as fungi, algae and bacteria, and the "remediation"—treating the situation.

In the Earth's biosphere, microorganisms grow in the widest range of habitats. They grow in soil, water, plants, animals, deep sea, and freezing ice environment. Their absolute numbers and their appetite for a wide range of chemicals make microorganisms the perfect candidate for acting as our environmental caretakers.

> *"Bioremediation is a waste management technique that includes the use of living organisms to eradicate or neutralize pollutants from a contaminated site."*

> *"Bioremediation is a 'treatment techniques' that uses naturally occurring organisms to break down harmful materials into less toxic or non-toxic materials."*

2.2 Bioremediation

Bioremediation technologies came into extensive usage and continue growing today at an exponential rate. Remediation of polluted sites using microbial process (bioremediation) has proven effective and reliable due to its eco-friendly features. In the past two decades, there have been recent developments in bioremediation techniques with the decisive goal being to successfully restore polluted environments in an economic, eco-friendly approach. Researchers have developed different bioremediation techniques that restore polluted environments. The micro-organisms used in bioremediation can be either indigenous or non-indigenous added to the contaminated site. Indigenous microorganisms present in polluted environments hold the key to solving most of the challenges associated with biodegradation and bioremediation of pollutant [1]. Environmentally friendly and cost effective are among the major advantages of bioremediation compared to both chemical and physical methods of remediation.

A mechanism of bioremediation is to reduce, detoxify, degrade, mineralize or transform more toxic pollutants to a less toxic. The pollutant removal process depends mainly on the pollutant nature, which includes pesticides, agrochemicals, chlorinated compounds, heavy metals, xenobiotic compounds, organic halogens, greenhouse gases, hydrocarbons, nuclear waste, dyes plastics and sludge. Cleaning

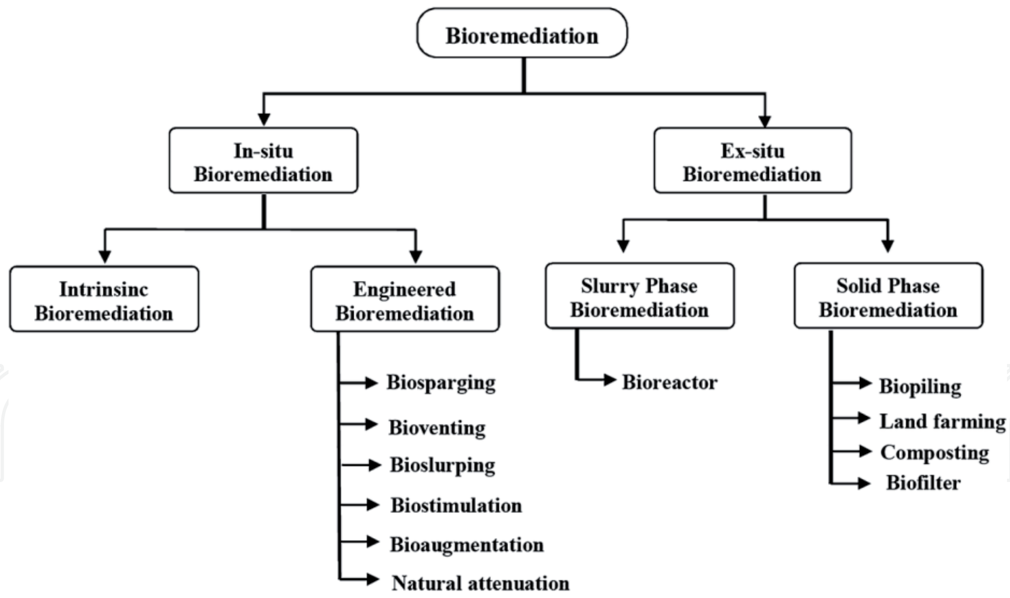

Figure 1.
Bioremediation approaches for environmental clean-up.

technique apply to remove toxic waste from polluted environment. Bioremediation is highly involved in degradation, eradication, immobilization, or detoxification diverse chemical wastes and physical hazardous materials from the surrounding through the all-inclusive and action of microorganisms (**Figure 1**).

3. Microorganisms used in bioremediation

Microorganisms play an important role on nutritional chains that are important part of the biological balance in life. Bioremediation involves the removal of the contaminated materials with the help of bacteria, fungi, algae and yeast. Microbes can grow at below zero temperature as well as extreme heat in the presence of hazardous compounds or any waste stream. The two characters of microbes are adaptability and biological system made them suitable for remediation process [2]. Carbon is the main requirement for microbial activity. Bioremediation process was carried out by microbial consortium in different environments. These microorganisms comprise *Achromobacter*, *Arthrobacter*, *Alcaligenes*, *Bacillus*, *Corynebacterium*, *Pseudomonas, Flavobacterium*, *Mycobacterium*, *Nitrosomonas*, *Xanthobacter*, etc. [3].

There are groups of microbes which are used in bioremediation such as:

Aerobic: aerobic bacteria have degradative capacities to degrade the complex compounds such as *Pseudomonas, Acinetobacter, Sphingomonas, Nocardia, Flavobacterium, Rhodococcus*, and *Mycobacterium.* These microbes have been reported to degrade pesticides, hydrocarbons, alkanes, and polyaromatic compounds. Many of these bacteria use the contaminants as carbon and energy source.

Anaerobic: anaerobic bacteria are not as regularly used as aerobic bacteria. There is an increasing interest in aerobic bacteria used for bioremediation of chlorinated aromatic compounds, polychlorinated biphenyls, and dechlorination of the solvent trichloroethylene and chloroform, degrading and converting pollutants to less toxic forms.

3.1 Factors affecting microbial bioremediation

Bioremediation process is degrading, removing, changing, immobilizing, or detoxifying various chemicals and physical pollutants from the environment through the activity of bacteria, fungi, algae and plants. Enzymatic metabolic pathways of microorganisms facilitate the progress of biochemical reactions that help in degradation of the pollutant. Microorganisms are act on the pollutants only when they have contact to the compounds which help them to generate energy and nutrients to multiply cells. The effectiveness of bioremediation depends on many factors; including, the chemical nature and concentration of pollutants, the physicochemical characteristics of the environment, and their accessibility to existing microorganisms [4].

The factors are mainly microbial population for degrading the pollutants, the accessibility of contaminants to the microbial population and environment factors like type of soils, pH, temperature, oxygen and nutrients.

3.2 Biotic or biological factors

Biotic factors are helpful for the degradation of organic compounds by microorganisms with insufficient carbon sources, antagonistic interactions among microorganisms or the protozoa and bacteriophages. The rate of contaminant degradation is frequently dependent on the concentration of the contaminant and the amount of catalyst present in biochemical reaction. The major biological factors are included enzyme activity, interaction (competition, succession, and predation), mutation, horizontal gene transfer, its growth for biomass production, population size and its composition [5, 6].

3.3 Abiotic or environmental factors

The interaction of environmental contaminants with metabolic activity, physicochemical properties of the microorganisms targeted during the process. The successful interaction between the microbes and pollutant depends on the environmental situations. Microbial growth and activity are depended on temperature, pH, moisture, soil structure, water solubility, nutrients, site conditions, oxygen content and redox potential, deficiency of resources and physico-chemical bioavailability of pollutants, concentration, chemical structure, type, solubility and toxicity. This above factors are control degradation kinetics [5, 7].

Biodegradation of pollutant can occur under range of pH (6.5–8.5) is generally optimal for biodegradation in most aquatic and terrestrial environment. Moisture affects the metabolism of contaminant because it depends on the kind and amount of soluble constituents that are accessible as well as the pH and osmotic pressure of terrestrial and aquatic systems [8].

4. Bioremediation technique

Superficially, bioremediation techniques can be carried out ex-situ and in-situ site of application (**Figure 1**). Pollutant nature, depth and amount of pollution, type of environment, location, cost, and environmental policies are the selection standards that are considered for selecting any bioremediation technique. Performance based on oxygen and nutrient concentrations, temperature, pH, and other abiotic factors that determine the success of bioremediation processes [9, 10].

Ex-situ bioremediation techniques involve digging pollutants from polluted sites and successively transporting them to another site for treatment. Ex-situ bioremediation techniques are regularly considered based on the depth of pollution, type of pollutant, degree of pollution, cost of treatment and geographical location of the polluted site. Performance standards also regulate the choice of ex-situ bioremediation techniques.

i. Solid-phase treatment

Solid-phase bioremediation is an ex-situ technology in which the contaminated soil is excavated and placed into piles. It is also includes organic waste like leaves, animal manures and agriculture wastes, domestic, industrial wastes and municipal wastes. Bacterial growth is moved through pipes that are distributed throughout the piles. Air pulling through the pipes is necessary for ventilation and microbial respiration. Solid-phase system required huge amount of space and cleanups require more time to complete as compared to slurry-phase processes. Solid-phase treatment processes include biopiles, windrows, land farming, composting, etc. [11].

ii. Slurry-phase bioremediation

Slurry-phase bioremediation is a relative more rapid process compared to the other treatment processes. Contaminated soil is combined with water, nutrient and oxygen in the bioreactor to create the optimum environment for the microorganisms to degrade the contaminants which are present in soil. This processing involves the separation of stones and rubbles from the contaminated soil. The added water concentration depends on the concentration of pollutants, the biodegradation process rate and the physicochemical properties of the soil. After completion of this process the soil is removed and dried up by using vacuum filters, pressure filters and centrifuges. The subsequent procedure is soil disposition and advance treatment of the resultant fluids.

5. Types of bioremediations

There are far more than nine types of bioremediation, but the following are the most common ways in which it is used.

5.1 Biopile

Bioremediation includes above-ground piling of dug polluted soil, followed by aeration and nutrient amendment to improve bioremediation by microbial metabolic activities. This technique comprises aeration, irrigation, nutrients, leachate collection and treatment bed systems. This specific ex-situ technique is progressively being measured due to its useful features with cost effectiveness, which allows operative biodegradation conditions includes pH, nutrient, temperature and aeration are effectively controlled. The biopile use to treat volatile low molecular weight pollutants; it can also be used effectively to remediate polluted very cold extreme environments [12–14]. The flexibility of biopile allows remediation time to be shortened as heating system can be integrated into biopile design to increase microbial activities and contaminant availability thus increasing the rate of biodegradation [15]. Additionally, heated air can be injected into biopile design to deliver air and heat in tandem, in order to facilitate enhanced bioremediation. Bulking agents such as straw saw dust, bark or wood chips and other organic materials have been added to enhance remediation process in a biopile construct. Although biopile systems connected to additional field ex-situ bioremediation techniques, such as land farming, bioventing, biosparging, robust engineering, maintenance and operation cost, lack of power supply at remote sites, which would facilitate constant air circulation in contaminated piled soil through air pump. Additional, extreme heating of air can lead to soil drying undertaking bioremediation, which will inhibit microbial activities and which stimulate volatilization than biodegradation [16].

5.2 Windrows

Windrows is bioremediation techniques depends on periodic rotating the piled polluted soil to improve bioremediation by increasing microbial degradation activities of native and transient hydrocarbonoclastic present in polluted soil. The periodic turning of polluted soil increase in aeration with addition of water, uniform distribution of nutrients, pollutants and microbial degradation activities, accordingly increase the rate of bioremediation, which can be proficient through acclimatization, biotransformation and mineralization. Windrow treatment as compared to biopile treatment, showed higher rate of hydrocarbon removal however, the effectiveness of the windrow for hydrocarbon removal from the soil [17]. However, periodic turning associated with windrow treatment not the best selection method to implement in bioremediation of soil polluted with toxic volatiles compounds. The use of windrow treatment has been associated in greenhouse gas (CH_4) release due to formation of anaerobic zone inside piled polluted soil, which frequently reduced aeration [18].

5.3 Land farming

Land farming is the simplest, outstanding bioremediation techniques due to its low cost and less equipment requirement for operation. It is mostly observed in ex-situ bioremediation, while in some cases of in-situ bioremediation technique. This consideration is due to the site of treatment. Pollutant depth is important in land farming which can be carried out ex-situ or in-situ. In land farming, polluted soils are regularly excavated and tilled and site of treatment speciously regulates the type of bioremediation. When excavated polluted soil is treated on-site, it is ex-situ as it has more in common than other ex-situ bioremediation techniques. Generally, excavated polluted soils are carefully applied on a fixed layer support above the ground surface to allow aerobic biodegradation of pollutant by autochthonous microorganisms [19]. Over all, land farming bioremediation technique is very simple to design and implement, requires low capital input and can be used to treat large volume of polluted soil with minimal environmental impact and energy requirement [20].

5.4 Bioreactor

Bioreactor is a vessel in which raw materials are converted to specific product(s) following series of biological reactions. There are different operational modes of bioreactors, which include: batch, fed-batch, sequencing batch, continuous and multistage. Bioreactor provides optimal growth conditions for bioremediation. Bioreactor filled with polluted samples for remediation process. The bioreactor based treatment of polluted soil has several advantages as compared to ex-situ bioremediation procedures. Bioreactor-based bioremediation process having excellent control of pH, temperature, agitation and aeration, substrate and inoculum concentrations efficiently reduces bioremediation time. The ability to control and manipulate process parameters in a bioreactor implies that biological reactions. The flexible nature of bioreactor designs allows maximum biological degradation while minimizing abiotic losses [21].

Advantages of ex-situ bioremediation

- Suitable for a wide range of contaminants
- Suitability relatively simple to assess from site investigation data

- Biodegradation are greater in a bioreactor system than or in solid-phase systems because the contaminated environment is more manageable and more controllable and predictable.

Disadvantages

- Not applicable to heavy metal contamination or chlorinated hydrocarbons such as trichloroethylene.
- Non-permeable soil requires additional processing.
- The contaminant can be stripped from soil via soil washing or physical extraction before being placed in bioreactor.

5.4.1 In-situ bioremediation techniques

These techniques comprise treating polluted substances at the pollution site. It does not need any excavation and by little or no disturbance in soil construction. Perfectly, these techniques should to be cost effective compared to ex-situ bioremediation techniques. Some in-situ bioremediation techniques like bioventing, biosparging and phytoremediation may be enhanced, while others may be progress without any form of improvement such as intrinsic bioremediation or natural attenuation. In-situ bioremediation techniques have been effectively used to treat chlorinated solvents, heavy metals, dyes, and hydrocarbons polluted sites [22–24].

5.4.2 Types of in-situ bioremediation

In-situ bioremediation is two types; these are intrinsic and engineered bioremediation.

i. Intrinsic bioremediation

Intrinsic bioremediation also known as natural reduction is an in-situ bioremediation technique, which involves passive remediation of polluted sites, without any external force (human intervention). This process deals with stimulation of indigenous or naturally occurring microbial population. The process based on both microbial aerobic and anaerobic processes to biodegrade polluting constituents containing those that are recalcitrant. The absence of external force implies that the technique is less expensive compared to other in-situ techniques.

ii. Engineered in-situ bioremediation

The second approach involves the introduction of certain microorganism to the site of contamination. Genetically Engineered microorganisms used in the in-situ bioremediation accelerate the degradation process by enhancing the physicochemical conditions to encourage the growth of microorganisms.

5.5 Bioventing

Bioventing techniques involve controlled stimulation of airflow by delivering oxygen to unsaturated (vadose) zone in order to increase activities of indigenous microbes for bioremediation. In bioventing, amendments are made by adding nutrients and moisture to increase bioremediation. That will achieve microbial transformation of pollutants to a harmless state. This technique has gained popularity among other in-situ bioremediation techniques [25].

5.6 Bioslurping

This technique combines vacuum-enhanced pumping, soil vapor extraction and bioventing to achieve soil and ground water remediation by indirect providing of oxygen and stimulation of contaminant biodegradation [26]. This technique is planned for products recovery from remediating capillary, light non-aqueous phase liquids (LNAPLs), unsaturated and saturated zones. This technique used to remediate soils which are contaminated with volatile and semi-volatile organic compounds. The method uses a "slurp" that spreads into the free product layer, which pulls up liquids from this layer. The pumping machine transports LNAPLs to the surface by upward movement, where it becomes separated from air and water. In this technique, soil moisture bounds air permeability and declines oxygen transfer rate, which reducing microbial activities. Although this technique is not suitable for low permeable soil remediation, it is cost effective operation procedure due to less amount of ground water, minimizes storage, treatment and disposal costs.

5.7 Biosparging

This technique is similar to bioventing in this air is injected into soil subsurface to improve microbial activities which stimulate pollutant removal from polluted sites. However, in bioventing, air is injected in saturated zone, which can help in upward movement of volatile organic compounds to the unsaturated zone to stimulate biodegradation process. The efficiency of biosparging depends on two major factors specifically soil permeability and pollutant biodegradability. In bioventing and soil vapor extraction (SVE), biosparing operation is closely correlated technique known as in-situ air sparging (IAS), which depend on high air-flow rates for volatilization of pollutant, whereas biosparging stimulates biodegradation. Biosparging has been generally used in treating aquifers contaminated with diesel and kerosene.

5.8 Phytoremediation

Phytoremediation is depolluting the contaminated soils. This technique based on plant interactions like physical, chemical, biological, microbiological and biochemical in contaminated sites to diminish the toxic properties of pollutants. Which is depending on pollutant amount and nature, there are several mechanisms such as extraction, degradation, filtration, accumulation, stabilization and volatilization involved in phytoremediation. Pollutants like heavy metals and radionuclides are commonly removed by extraction, transformation and sequestration. Organic pollutants hydrocarbons and chlorinated compounds are mostly removed by degradation, rhizoremediation, stabilization and volatilization, with mineralization being possible when some plants such as willow and alfalfa are used [27, 28].

Some important factors of plant as a phytoremediator include: root system, which may be fibrous or tap depending on the depth of pollutant, above ground biomass, toxicity of pollutant to plant, plant existence and its adaptability to predominant environmental conditions, plant growth rate, site monitoring and above all, time mandatory to achieve the preferred level of cleanliness. In addition, the plant must be resistant to diseases and pests [29]. In phytoremediation removal of pollutant includes uptake, translocation from roots to shoots. Further, translocation and accumulation depends on transpiration and partitioning [30]. However, the process is possible to change, depending on other factors such as nature of contaminant and plant. The mostly plants growing in any polluted site are good phytoremediators. Therefore, the success of any phytoremediation method mainly depends on improving the remediation potentials of native plants growing in polluted sites either by bioaugmentation with endogenous or exogenous plant. One of the major advantages of using plants to remediate polluted site is that some precious metals can bioaccumulate in some plants and recovered after remediation, a process known as phytomining.

5.9 Permeable reactive barrier (PRB)

This technique is commonly observed as a physical method for remediating contaminated groundwater. However, biological mechanisms are precipitation degradation and sorption of pollutant removal used in PRB method. The substitute terms such as biological PRB, bio-enhanced PRB, passive bioreactive barrier, have been suggested to accommodate the biotechnology and bioremediation aspect of the technique. In general, PRB is an in-situ technique used for remediating heavy metals and chlorinated compounds in groundwater pollution [31, 32].

5.10 Advantages of in-situ bioremediation

- In-situ bioremediation methods do not required excavation of the contaminated soil.
- This method provides volumetric treatment, treating both dissolved and solid contaminants.
- The time required to treat sub-surface pollution using accelerated in-situ bioremediation can often be faster than pump and treat processes.
- It may be possible to completely transform organic contaminants to innocuous substances like carbon dioxide, water and ethane.
- It is a cost effective method because there is minimal site disruption.

5.11 Limitation of in-situ bioremediation

Depending on specific site, some contaminants may not be absolutely transformed to harmless products.

If transformation stops at an intermediate compound, the intermediate may be more toxic and/or mobile than parent compound some are recalcitrant contaminants cannot be biodegradable.

When incorrectly applied, injection wells may become blocked by profuse microbial growth due to addition of nutrients, electron donor and electron acceptor.

Heavy metals and organic compounds concentration inhibit activity of indigenous microorganisms.

In-situ bioremediation usually required microorganism's acclimatization, which may not develop for spills and recalcitrant compounds.

6. Bioremediation prospects

Bioremediation techniques are varied and have demonstrated effective in restoring polluted sites. Microorganisms play fundamental role in bioremediation;

consequently, their diversity, abundance and community structure in polluted environments offer insight into the chance of any bioremediation technique providing other environmental factors, which can inhibit microbial activities. Advanced Molecular techniques such as 'Omics' includes genomics, proteomics, metabolomics and transcriptomics have contributed towards microbial identification, functions, metabolic and catabolic pathways, with microbial based methods. Nutrient availability, low population or absence of microbes with degradative capabilities, and pollutant bioavailability may delay the achievement of bioremediation. Since bioremediation depends on microbial process, biostimulation and bioaugmentation approaches speed up microbial activities in polluted sites. Biostimulation increase microbial activities by the addition of nutrients to a polluted sample. Microorganisms are abundantly present in different type of environmental condition, it is noticeable that pollutant degrading microbes are naturally present in polluted contaminated sites, their growth and metabolic activities may depends on pollutant type and concentration; later, we can use of agro-industrial wastes, which contains nitrogen, phosphorus and potassium as a nutrient source most polluted sites. Microbial consortium has been reported to degrade pollutants more efficiently than pure isolates [33].

This activity due to metabolic diversities of individual isolates, which potency create from their isolation source, adaptation process, pollutant composition, and synergistic effects, which may lead to complete and rapid degradation of pollutants when such isolates are mixed together [34]. Additional so, both bioaugmentation and biostimulation were effective in removing pollutant such as polyaromatic hydrocarbons (PAHs) from heavily polluted sample compared to non-amended setup (control) [35].

Although bioaugmentation has recognized effective method, it has been shown to increase the degradation of many compounds. If proper biodegrading microorganisms are not present in soil or if microbial populations decreased because of contaminant toxicity, specific microorganisms can be added as "introduced organisms" to improve the current populations and the possibility that the inoculated microorganisms may not survive in the new environment make bioaugmentation a very uncertain method. This process is known as bioaugmentation. Bioremediation technique in which natural or genetically engineered bacteria with unique metabolic profiles are used to treat sewage or contaminated water or soil. The use of alginate, agar, agarose, gelatin, gellan gum and polyurethane as carrier materials solve some of the challenges associated with bioaugmentation [36].

Biosurfactants are chemical equivalents having ecofriendly and biodegradable properties. However, high construction cost and low scalability application of biosurfactants to polluted site are uneconomical. Agro-industrial wastes combination are nutrient sources for development of biosurfactant producers during fermentation process. Application of several bioremediation techniques will help increase remediation efficiency [37].

Enhancing bioremediation ability with organized use of genetically engineered microorganisms (GEM) is a favorable approach. This is due to possibility of engineering a designer biocatalyst target pollutant including recalcitrant compounds by combining a novel and efficient metabolic pathways, widening the substrate range of existing pathways and increasing stability of catabolic activity [38].

However, parallel gene transfer and multiplication of GEM in an environmental application are encouraging approach. Bacterial containment systems, in which any GEM escaping an environment to reconstruct polluted environment.

Further, derivative pathway of genetically engineering microorganisms with a target polluted compound using biological approach could increase bioremediation efficiency. Nanomaterials decline the toxicity of pollutant to microorganisms because nanomaterials having increase surface area and lower activation energy, which reduce time and cost of bioremediation [39].

7. Bioremediation applications

Bioremediation must be considered as appropriate methods that can applied to all states of matter in the environment

i. Solids (soils, sediment and sludge)

ii. Liquids (ground water, surface water and industrial waste water

iii. Gases (industrial air emissions)

iv. Sub-surface environments (saturated and vadose zones).

The general approaches to bioremediation are the (i) intrinsic (natural) bioremediation, (ii) biosimulation (environmental modifications, through nutrient application and aeration, and (iii) bioaugmentation (addition of microbes).

The biological community exploited for bioremediation generally consists of the native soil microflora. However, higher plants can also be manipulated to enhance toxicant removal (phytoremediation), especially for remediation of metal contaminated soils.

7.1 Advantage and disadvantage

All bioremediation techniques have its own advantage and disadvantage because it has its own specific applications.

7.1.1 The advantage of bioremediation

- It is a natural process; it takes a little time, as an adequate waste treatment process for contaminated material such as soil. Microbes able to degrade the contaminant, the biodegradative populations become reduced. The treatment products are commonly harmless including cell biomass, water and carbon dioxide.

- It needs a very less effort and can commonly carry out on site, regularly without disturbing normal microbial activities. This also eradicates the transport amount of waste off site and the possible threats to human health and the environment.

- It is functional in a cost effective process as comparison to other conventional methods that are used for clean-up of toxic hazardous waste regularly for the treatment of oil contaminated sites. It also supports in complete degradation of the pollutants; many of the toxic hazardous compounds can be transformed to less harmful products and disposal of contaminated material.

- It does not use any dangerous chemicals. Nutrients especially fertilizers added to make active and fast microbial growth. Because of bioremediation change harmful chemicals into water and harmless gases, the harmful chemicals are completely destroyed.

- Simple, less labor intensive and cheap due to their natural role in the environment.

- Contaminants are destroyed, not simply transferred to different environmental.
- Nonintrusive, possibly allowing for continued site use.
- Current way of remediating environment from large contaminates and acts as ecofriendly sustainable opportunities.

7.1.2 The disadvantage of bioremediation

- It is restricted for biodegradable compounds. Not all compounds are disposed to quick and complete degradation process.
- There are particular new products of biodegradation may be more toxic than the initial compounds and persist in environment.
- Biological processes are highly specific, ecofriendly which includes the presence of metabolically active microbial populations, suitable environmental growth conditions and availability of nutrients and contaminants.
- It is demanding to encourage the process from bench and pilot-scale to large-scale field operations. Contaminants may be present as solids, liquids and gases. It often takes longer than other treatment preferences, such as excavation and removal of soil or incineration.
- 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.

7.2 Limitations of bioremediation

Bioremediation is limited to those compounds that are biodegradable. This method is susceptible to rapid and complete degradation. Products of biodegradation may be more persistent or toxic than the parent compound in the environment.

1. Specificity

Biological processes are highly specific. Important site factors mandatory for success include the presence of metabolically capable microbial populations, suitable environmental growth conditions, and appropriate levels of nutrients and contaminants.

2. Scale up limitation

It is difficult to scale up bioremediation process from batch and pilot scale studies applicable to large scale field operations.

3. Technological advancement

More research is required to develop modern engineer bioremediation technologies that are suitable for sites with composite combinations of contaminants that are not equally distributed in the environment. It may be present as solids, liquids and gases forms.

4. Time taking process

Bioremediation takes longer time compare to other treatment options, such as excavation and removal of soil from contaminated site.

5. Regulatory uncertainty

We are not certain to say that remediation is 100% completed, as there is no accepted definition of clean. Due to that performance evaluation of bioremediation is difficult, and there is no acceptable endpoint for bioremediation treatments.

8. Conclusion

Biodegradation is very fruitful and attractive option to remediating, cleaning, managing and recovering technique for solving polluted environment through microbial activity. The speed of undesirable waste substances degradation is determined in competition with in biological agents like fungi, bacterial, algae inadequate supply with essential nutrient, uncomfortable external abiotic conditions (aeration, moisture, pH, temperature), and low bioavailability. Bioremediation depending on several factors, which include but not limited to cost, site characteristics, type and concentration of pollutants. The leading step to a successful bioremediation is site description, which helps create the most suitable and promising bioremediation technique (ex-situ or in-situ). Ex-situ bioremediation techniques tend to be more costly due to excavation and transportation from archeological site. However, they can be used to treat wider range of pollutants. In contrast, in-situ techniques have no extra cost for excavation; however, on-site installation cost of equipment, attached with effectively and control the subsurface of polluted site can reduce some ineffective in-situ bioremediation methods. Geological characteristics of polluted sites comprising soil, pollutant type and depth, human habitation site and performance of every bioremediation technique should be integrated in determining the most appropriate and operative bioremediation technique to successfully treatment of polluted sites.

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