Chapter

Bioremediation Techniques for Soil Pollution: An Introduction

Anita Verma

Abstract

Environmental pollution has been on the rise in the past few decades owing to increased human activities on energy reservoirs, unsafe agricultural practices and rapid industrialization. Soil pollution is one of the major worry among all because soil contamination can harm the humans by consumption of food grown in polluted soil or it can cause infertility to soil and lower the productivity, Among the pollutants that are of environmental and public health concerns due to their toxicities are: heavy metals, nuclear wastes, pesticides, greenhouse gases, and hydrocarbons. So this chapter will include; Sources of soil pollution and remediation of polluted sites using biological means has proven effective and reliable due to its eco-friendly features. Bio-remediation can either be carried out ex situ or in situ, depending on several factors, which include site characteristics, type and concentration of pollutants. It also seen as a solution for emerging contaminant problems.

Keywords: soil pollution, bio-remediation, ex situ bio-remediation, in situ bio-remediation

1. Introduction

Soil is an essential a neighborhood of the common habitat. It's pretty much as significant as plants, creatures, rocks, landforms, loch and waterways. It is a living space for a genuine scope of living beings. It goes about as stream control for water and synthetic substances between the environment and along these lines the world, and furthermore both as a source and store for gases (like oxygen and carbon dioxide) inside the climate. Soils do not simply influence characteristic cycles yet additionally record human exercises both at this and inside the past.

Soil is dynamic organically and a permeable medium that has created inside the highest layer of Earth's covering. Soil is one of the corpus foundations of life on Earth, which might be a supply of water and supplements, as a mechanism for the filtration and breakdown of squanders, and as a functioning member inside the cycling of carbon and different components through the environment accessible universally. It's gotten from enduring cycles driven by natural, climatic, geologic, and geographical impacts.

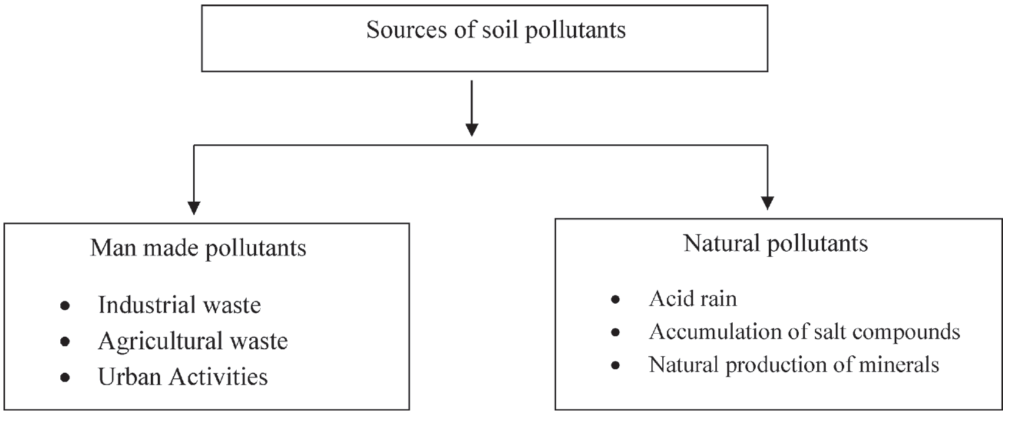
Soil is the linkage between the different ecosystems like biosphere, atmosphere, and hydrosphere. So, the soils are fundamental in the preservation of environmental quality at local, regional, and worldwide level. For example, its buffering capacity contributes to water quality, since the ability to act as a sink for contaminants can have an important role in controlling the negative impacts of pollution on other environment. Researchers are trying to develop and model different bioremediation techniques; however, there is no single bioremediation technique that treats all types of contamination and to restore polluted environments. Bioremediation is a natural process, which relies on bacteria, fungi, and plants to remove, reduce, degrade, or immobilize environmental pollutants from soil and water, thus restoring contaminated sites to a relatively clean nontoxic environment [1].

It is now recognized that, soil is considered a vital resource, and due to its slow formation, it can be considered nonrenewable. Moreover, it has impacts on environmental, economic, and cultural activities. These techniques are environmentally friendly and cost effective features are the major advantages of bioremediation compared to both chemical and physical methods of remediation. Thus far, several good definitions have been given to bioremediation, with particular emphasis on one of the processes.

2. Soil pollution

Soil contamination is that the decrease inside the efficiency of soil in light of the presence of soil toxins. Soil toxins adversely affect the actual substance and organic properties of the dirt and decrease its profitability. Pesticides, composts, natural excrement, synthetic substances, radioactive squanders, disposed of food, garments, cowhide merchandise, plastics, paper, bottles, tins-jars and cadavers all contribute towards causing soil contamination. Synthetic substances like iron lead mercury, copper, zinc, cadmium, aluminum, cyanides, acids and soluble bases and so on are available in modern squanders and arrive at the dirt either straightforwardly with water or in a roundabout way through air. (for example through corrosive downpour).

Soil contamination can cause contamination if harmful synthetics drain into groundwater, or whenever sullied spillover arrives at streams, lakes, or seas. Soil additionally normally adds to contamination by delivering unstable mixtures into the environment. Nitrogen escapes through alkali volatilization and denitrification. The disintegration of natural materials in soil can deliver sulfur dioxide and other sulfur compounds, causing corrosive downpour. Substantial metals and other possibly poisonous components are the principal genuine soil toxins in sewage. Sewage slop contains substantial metals and, whenever applied over and again or in huge sums, the treated soil may gather weighty metals and thus it become incapable to try and support blossoms.



3. Man made pollutants

3.1 Agricultural pollution

Agricultural processes contribute to soil pollution. For increasing increase crop yield fertilizers are used which also cause pollution that impacts soil quality. Use of pesticides also harms plants and animals by contaminating the soil, these chemicals get deep inside the soil and poison the ground water system and runoff of these chemicals by rain and irrigation also contaminate the local water system and causes eutrophication of fresh water body. Phosphate is the main contributor to eutrophication its high concentration promotes Cyanobacteria and Algae growth which ultimately reduces dissolved oxygen in water [2].

3.2 Industrial waste

Most of the pollution is caused by industrial waste products and improper disposal of waste contaminates the soil with harmful chemicals. These pollutants affect plant and animal species and local water supplies and drinking water. On the other hand toxic fumes from the regulated landfills contain chemicals that can fall back to the earth in the form of acid rain and can damage the soil profile. Industrial activities like leads to acidification of soil and contamination due to the disposal of industrial waste, heavy metals, toxic chemicals, dumping oil and fuel, etc.

3.3 Urban activities

Human activities can lead to soil pollution directly and indirectly. For example improper drainage and increase run-off contaminates the nearby land areas or streams. Unorganized disposal of trash breaks down into the soil and it deposits in a number of chemical and pollutants into the soil. These may again seep into groundwater or wash away in local water system and excess waste deposition increases the presence of bacteria in the soil which leads to the generation of methane gas from decomposition activities by bacteria contributing to global warming and poor air quality. It also creates foul odors and can impact quality of life [3].

3.4 Acid rain

Acid rain primarily caused by Sulfur dioxide (SO2), oxides of nitrogen and ozone to some extent. Acid rain is caused when pollutants present in the air mixes up with the rain and fall back on the ground. Sulfuric and nitric acid solutions cause acidity in rainwater. Acid rain decreases the pH of the soil, causing its acidity to increase, which decreases the level of important nutrients found in the soil [4]. Soils low in cation exchange capacity and base saturation are the most sensitive to acid precipitation [5].

4. Natural source of soil pollution

Some of natural event also can be the cause of soil pollution like earthquakes, landslides, hurricanes, and flood. These natural disasters cause transpose to the composition of soil which leads to the contamination. For example weathering of naturally occurring sulphide-bearing rock make mineralized zones of arsenopyrite (gossans), Most of these minerals present a high spatial variability and many of them can be found in higher concentrations in deeper layers. However, As is slightly bioaccessible if getting from natural sources [6]. Soils and rocks are also natural sources of the radioactive gas Radon (Rn). High natural radioactivity is common in acidic igneous rocks, mainly in feldspar-rich rocks and illite-rich rocks.

However, There are other numerous of ways of soil contamination, for example, • Seepage from a landfill • Discharge of mechanical waste into the dirt • Percolation of defiled water into the dirt • Rupture of underground stockpiling tanks • Excess utilization of pesticides, herbicides or compost • Solid waste drainage • The most well-known synthetics associated with causing soil contamination are: • Petroleum hydrocarbons • Heavy metals • Solvents Soil contamination happens when these synthetic substances hold fast to the dirt, either from being straightforwardly spilled onto the dirt or through contact with soil that has effectively been tainted.

4.1 Effects of soil pollution

Impacts of soil pollution are not confined to soil and its biota but are carried over to every aspect of the environment and affect every organism from the earthworm to humans. Some of adverse effects are as follows:

a. **Human health**

Since we are dependent on the land for our food, pollution from the soil is transferred to us in this manner. Bioaccumulation of toxins occurs in our bodies, causing chronic poisoning, and leading to various diseases. Reproductive health, birth and developmental defects, neurologic effects, malnutrition, and mutations in the cells of the body leading to cancers; all these are on the increase today [7]. Considering direct impact of soil on human health because inhalation of polluted soil which have vaporized and contamination of it. Crops and plants grown on polluted soil absorb much of the pollution and then pass these on to us [8]. This could explain the sudden surge in small and terminal illnesses. Long term exposure to such soil can affect the genetic make-up of the body, causing congenital illnesses and can be carcinogenic, due to this congenital disorder or other chronic health problem created that cannot be cured easily. For example leukemia disease which is associated with higher concentration of benzene and its exposure is chronic to human health. Due to high concentration of mercury and cyclodienes, induce sufficient concentration of PCBs and cyclodienes can damage Kidney and liver toxicity. Carbamates and organophosphates can cause Neurological disorders. Arsenic, asbestos or dioxins, cause cancer and lower IQ caused by lead or arsenic, bone diseases through lead, fluoride or cadmium In fact, it can sicken the livestock to a considerable extent and cause food poisoning over a long period of time. The soil pollution can even lead to widespread famines if the plants are unable to grow in it.

b. **Growth of plants**

Contamination of soil can affect the ecological balance. Plants are mostly unable to adapt to the abrupt changes in the chemistry of the soil and this affects the microorganisms which are found in soil. This Substantial change causes soil disintegration. Enormous plots of land become infertile; unfit to help any life on it. Indeed, even the plants that do develop on these terrains will retain the poisons and move to the natural way of life. The natural equilibrium of any framework gets influenced because of the inescapable tainting of the soil. Most plants cannot adjust when the science of the soil changes so fundamentally in a brief timeframe. Growths and microbes found in the dirt that dilemma it together start to decrease, which makes an extra issue of soil disintegration. The fruitfulness gradually reduces, making land inadmissible for horticulture and any neighborhood vegetation to endure. The soil contamination makes enormous plots of land become dangerous to wellbeing. In contrast to deserts, which are appropriate for its local vegetation, such land cannot uphold most types of life.

c. **Air pollution**

Poisonous residue ascends from landfills alongside foul scent, contaminates the air and makes unfriendly impacts individuals who live close to them.

d. **Diminished Soil Fertility:**

The poisonous synthetics present in the dirt can diminish soil fertility and subsequently decline in the dirt yield. The defiled soil is then used to deliver leafy foods which needs quality supplements and may contain some harmful substance to cause genuine medical conditions in individuals burning-through them.

e. **Impact on scene and Odor contamination:**

Huge heaps of decline and trash being open unloaded and littered over a space ruins the serenity of the scene. The emanation of harmful and foul gases from landfills dirties the climate and causes genuine consequences for wellbeing of certain individuals. The horrendous smell makes burden others.

f. **Changes in Soil Structure:**

The passing of many soil living beings (for example night crawlers, creepy crawlies and microorganisms) in the dirt can prompt modification in soil structure. Aside from that, it could likewise compel their hunters to move to different spots looking for food.

g. **Impact on Ecosystem and Biodiversity:**

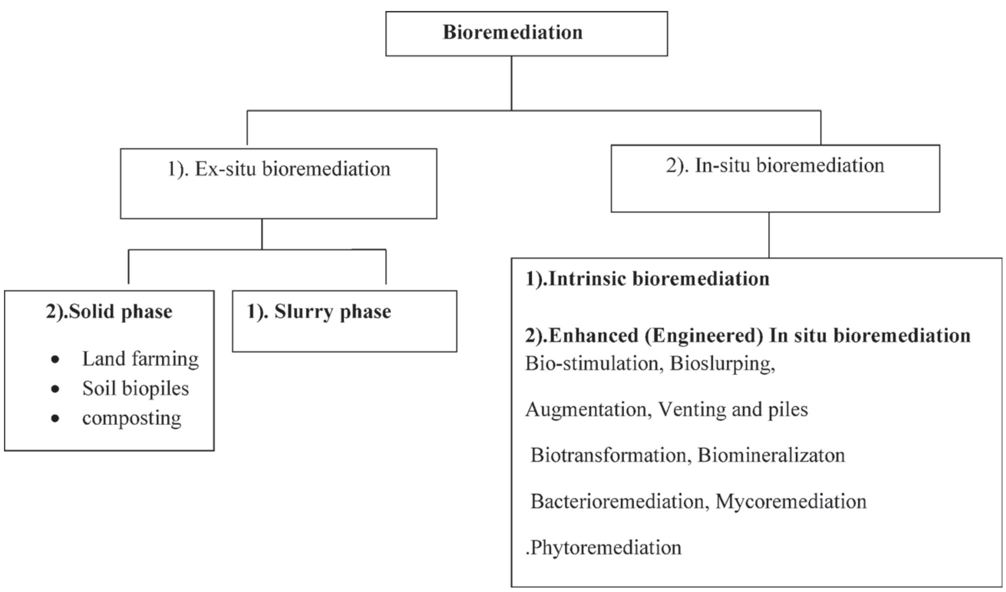
Soil contamination can prompt the absence of biodiversity in an environment. The existence of bird, creepy crawly, well evolved creature and reptile species that live in the dirt can get influenced by contamination. The dirt is a significant environment.

h. **Tainting of Water Sources:**

When it downpours, surface run-off conveys debased soil into water sources causing water contamination. Toxins can likewise penetrate down to debase ground water. The defiled water is subsequently unsuitable for both creature and human utilization. It will likewise influence amphibian daily routine since the living beings that experience in these water bodies will discover their living spaces inhabitable.

5. Bioremediation

Remediation means to get rid of an issue and if it is associated with taking care of an ecological issue like soil and groundwater contamination is called bio-remediation. Bioremediation is a mechanism which utilizes the living microorganisms to reduce natural contaminations or to anticipate contamination [9]. It is an evolution towards elimination of toxins from the climate in this way reestablishing the first characteristic environmental factors and forestalling further contamination. Bioremediation also can be a permanent in situ solution for contamination instead of simply translocating the problem. Remediation of heavy metals, metalloids, or other inorganic pollutants from soil or water can be done by this technique [10]. It is a cost-effective, efficient, novel, eco-friendly, and solar-driven technology with good public acceptance as compared with other engineering techniques.



A. Based on applied strategies: bioremediation techniques applied on the basis of strategies can be classified in two categories.
Ex-situ bioremediation.
In-situ bioremediation.

5.1 Ex-situ bioremediation

Ex-situ as name suggests its mean to remove contamination mat to a remote treatment location. This classification is not much popular because it involves the big task of excavating polluted soil and transports it to offsite. The basic principal of ex situ remediation is to introducing the correct soil oxygen, moisture and nutrient conditions on offsite [11]. However, Ex situ bioremediation process poses a hazard to spreading contamination or risking an accidental spill during transport [12]. There are two technique classes can be applied explained bellow.

5.1.1 Slurry phase

This technique involves the process of combining contaminated soil with water and other additives in a large bio-reactor and mixed to keep the indigenous microorganisms in contact with the contaminants. Essential nutrients, oxygen are added and the conditions in the bio-reactor are ensured at optimum environment for the micro-organisms to degrade the contaminants. After completion of the treatment, the water is removed from the solids -wastewater is disposed and further treated if still contaminated. Slurry-phase is a relatively rapid process compared to other biological treatment processes specifically for contaminated clays [13].

5.1.2 Solid phase

Solid phase treatment use to treats soils in above-ground treatment area. This area equipped with collection systems to check the contaminants from escaping the treatment. The parameters like moisture, heat, nutrients, and oxygen are controlled to enhance rate of degradation. Solid-phase systems are simple to process and maintain in spite of, it require a large amount of space and more time of treatment than slurry-phase processes. This treatment can be achieved by following techniques [14].

5.1.2.1 Land farming

This technique basically stimulates biodegradation through indigenous microorganisms and facilitate aerobic degradation of contaminates. It is done by a simple methodology technique in which contaminated soil is excavated and spread over a prepared bed and regularly until pollutants are degraded. For promoting the growth of the indigenous species some nutrients and minerals are also added.

5.1.2.2 Soil biopiles

This biodegradation technique used for the remediation of excavated soil contaminated with petroleum contents. Soil biopiles also known as biocells. This technology involves the accumulation of contaminated soil into piles and the stimulation of microbial activity either aerobically or by adding nutrients, minerals or moisture [13]. A typical height of biopiles can be three and ten feet. This technology also uses oxygen as a method to stimulate bacterial growth. Biopiles are aerated by forcing air to move by injection through perforated piping placed throughout the pile [14].

5.1.2.3 Composting

Composting involves mixing the contaminated soil with a biomass such as straw, hay, or corncobs which make it suitable to deliver the optimum levels of air and water to the microorganisms. Composting involves the locating of the contaminated soil in treatment vessels and it is mixed there for aeration. Window composting a type of composting process in which the soil is placed in long piles named as windows and mixed by tractors regularly. A ratio of 75% contaminated soil to 25% compost use for composting. This ratio is depending on the variability of soil type, contaminants level and characteristics. Compost remediation is known as a faster remediation because it can remediate in weeks [15].

5.2 In-situ bioremediation

Bioremediation process is done at the contamination site defines the in-situ method. In situ is the preferred bioremediation method, as it requires less mechanical efforts to eliminates spreading contaminants and prevent the spread of pollutant through transportation or pumping away to other treatment locations.

In situ bioremediation are biological processes which include microorganisms metabolize organic contaminants to inorganic material, such as carbon dioxide, methane, water and inorganic salts. This process can be achieved either in natural or engineered conditions [16].

5.2.1 Types of In situ bioremediation

5.2.1.1 Intrinsic bioremediation

Intrinsic bioremediation is a process for converting environmental pollutants degrades to non-toxic forms through the immanent abilities of naturally occurring microbial population at the site. This process is usually employed in underground places as such underground petroleum tanks. Intrinsic bioremediation manages the innate capabilities of naturally occurring microbial communities to degrade environmental pollutants without modified or taking any engineering steps to accelerate the process [11]. This technique deals with stimulation of indigenous microbial population by feeding them nutrients and oxygen to increase their metabolic activity.

5.2.1.2 Enhanced (engineered) In situ bioremediation

As the name suggested this technique involves the introduction of specific microorganism to the contaminated site. Engineered in situ bioremediation accelerates the degradation process by enhancing the physicochemical conditions to increase the growth of microorganism.

A. **Bio-venting**

Bio-venting is an in situ remediation technique that uses microorganisms to degrade organic constituents adsorbed on soils [17]. This technique involves regulated stimulation of airflow for increasing oxygen to unsaturated zone for enhances the bioremediation, by increasing activities of indigenous microbes. In the process of bio-venting, amendments are done by adding nutrients and moisture to increase bioremediation to achieve microbial transformation of pollutants to a nontoxic state. This technique has gained popularity among other in situ bioremediation techniques especially in restoring sites polluted with light spilled petroleum products. Bioventing primarily use for the degradation of adsorbed fuel residuals, and also can use in the degradation of volatile organic compounds (VOCs) through biologically active soil.

B. **Bioslurping**

Bioslurping technique is the combination of bioventing and vacuum-enhanced pumping of soil and groundwater remediation by indirect provision of oxygen and stimulation of contaminant biodegradation [18]. This technique uses a "slurp" that extends into the free product layer, which draws up liquids (free products and soil gas) from this layer in a manner similar to that of how a straw draws liquid from any vessel. The bioslurping system is constituted by a well connected to an adjustable length called "slurp tube" is installed, and this slurp tube, connected to a vacuum pump, which is lowered into the light non-aqueous phase liquids (LNAPL) layer, and pumping begins to remove free product along with some groundwater. The vacuum-induced negative pressure zone in the well promotes LNAPL flow towards the well and also draws LNAPL trapped in small pore spaces above the water table. This technique used to remediate soils contaminated with volatile and semi-volatile organic compounds

C. **Biosparging**

Biosparging is basically a biological approach which removes the aromatic compounds contamination like benzene, toluene, ethylbenzene, xylene and neptthalene from an area. This process involves the loading of specific aerobic bacteria to break down the mineral oil and aromatic compounds into simpler and useful form. This technique is similar to bioventing where air is incorporate into soil subsurface to stimulate microbial activities to enhance pollutant removal from polluted sites. In biosparging air is injected at the saturated zone, which can cause upward movement of volatile organic compounds to the unsaturated zone to promote biodegradation [19]. There are two major factors which affect the biosparging process namely:

- Soil permeability (which determines pollutant bioavailability to microorganisms)
- Pollutant biodegradability

D. **Bioaugmentation**

Bioaugmentation is arrangement to enrich the existing microorganism population and make it more effective in reducing the level of contamination. This technique refers to the addition of organic culture to the contaminated soil and make environment of the site similar to a bioreactor. There are two common options can be used one is addition of a pre-adapted pure bacterial strain and second is addition of a pre-adapted consortium to the contaminated site. Bioaugmentation is mainly used in oil contaminated site for bioremediation. Bioaugmentation is a low-cost method in comparision of other methods of treating wastewater and soil contamination [20].

E. **Phytoremediation**

The direct use of green plants and their associated microorganisms to stabilize or reduce contamination in soils, sludges, sediments, surface water, or ground water is defined as Phytoremediation. This technique depends on the use of plant interactions (physical, biochemical, biological, chemical and microbiological) to contaminated sites to mitigate the toxic effects of pollutants. It is an alternative technology that can be used along with or in place of mechanical conventional clean-up technologies that often require high capital inputs and are energy intensive. Area with low concentrations of contaminants over large cleanup areas and at shallow depths presents especially favorable conditions for phytoremediation. Depending on pollutant type (elemental or organic), there are several mechanisms (accumulation or extraction, degradation, filtration, stabilization and volatilization) involved in phytoremediation [21]. Elemental pollutants (toxic heavy metals and radionuclides) are mostly removed by extraction, transformation and sequestration.

i. **Phytostabilization** - using plants to reduce heavy metal bioavailability in soil.

ii. **Phytoextraction** — using plants to extract and remove heavy metals from soil.

iii. **Phytovolatilization** — using plants to absorb heavy metal from soil and release into the atmosphere as volatile compounds.

iv. **Phytofiltration** — using hydroponically cultured plants to absorb or adsorb heavy metal ions from groundwater and aqueous waste.

1. **Phytostabilization**

The phytostabilization process involves plants which established and function primarily to accumulate metals into tissues of root or aid in their precipitation in the root zone. This technique is based on the chemical stabilization of heavy metals using various non-organic and/or organic soil additives in connection with adequately chosen plant species [22]. Species which will be resistant to specific conditions present in the soil, such as low pH and high concentrations of heavy metals, ought to be selecting. Phytostabilization reduces the mobility of contaminants, and help to minimize the risk, of inorganic contaminants within the site. This technology does not generate contaminated secondary waste that needs further treatment. This technique basically limits the bioavailability of heavy metals and to restore adequate soil quality.

2. **Phytoextraction**

Phytoextraction is a phytoremediation technique that uses plants to uptake and removes metals and other contaminants from soil or water [22]. This technology can be used to reduce both organic and inorganic pollutants from the soil, water and the air as well. This technology seems to be similar as solar driven pumps which can extract and concentrate certain elements from their environment. This should be achieved at a lower cost than any alternate technology as it only requires the identification and planting of such plant which possess the ability of hyperaccumulation. The ability to accumulate heavy metals varies significantly between species and between cultivars within a species [23].

3. **Phytovolatilization**

Phytovolatilization, employs the plant-mediated uptake of contaminants and transforms them into volatile compounds, and subsequently releases these compounds in the atmosphere. In this technique plant absorbs organic pollutants an water while growing it travels from root to other parts of the plants as same or in an altered form due to its metabolic and transpiration pull.

4. **Phytofiltration**

Phytofiltration technique is manly use to treat contaminated water. This technique involves, high metal-accumulating plants which function as biofilters, and it can be also effective in sequestering metals from polluted waters [24]. In this technique the polluteded water is either collected from a waste site or brought to the plants, or the plants are planted in the contaminated area, where the roots take up the waste water and the dissolved contaminants [25]. Many plant species naturally uptake heavy metals and other contaminant due to this it is a cost effective procedure for remediation.

5. **Phytodegradation**

   Phytodegradation technique refers to the degradation of organic contaminants through the enzymatic activates of plants. The plant releases enzymes from roots, or through metabolic activities within plant tissues. In phytodegradation organic contaminants are taken up by roots and metabolized in plant tissues to less toxic substances [26]. Phytodegradation process can degrade hydrophobic organic contaminants more efficiently.

6. **Mycoremediation**

   Mycoremediation is a technique of using fungus as a bioremediator. This biotechniques uses particular fungi that release enzymes which can degrade several pollutants and found to be promising strategies in the removal of contaminant with in a site. Mycoremediation is an efficient and economical technique as well [27].

6. Conclusion

Bioremediation is an effective technique available to clean up contaminated sites. The idea of bioremediation has a long history. However, other applications are relatively new and many other applications are emerging or being developed. This process can be aerobic or anaerobic depending on the microorganisms and the electron acceptors available. This process may be natural (intrinsic bioremediation) or it may be enhanced by man (engineered bioremediation). Several remediation approaches, particularly physical systems, involve the treatment of aqueous phase pollutants and, here, the distinction between soil and groundwater is of limited practical significance. Remediation approaches aimed primarily at treating or containing groundwater within 'geological' materials will be mentioned only briefly, whereas those commonly used for dual purposes will be considered in more detail. These technologies offer an efficient and cost effective way to treat contaminated ground water and soil.

There are other common methods of preventing soil pollution include reforestation and recycling of waste materials. De forestation often leads to erosion of the soil, which leads to soil pollution due to the loss of fertility of the soil. Thus, reforestation is an effective method of preventing soil pollution. In addition, reducing the volume of refuse or waste in landfills by recycling materials such as plastics, papers and various other materials is another effective and common method of preventing the phenomenon of soil pollution.

Overall study suggested that Pollution is a threat to our health and damages the environment and damage to soils which affects the ability to grow crops. Bioremediation can help to reduce and remove the pollution and to provide clean water, air and healthy soils for future generations. The bioremediation process is completely natural process with very less harmful side effects. It carried out in situ for most applications which do not require dangerous transport. It creates relatively few harmful byproducts. Bioremediation is way cheaper than most remediation methods because it does not require substantial equipment or labor.

Author details

Anita Verma
Department of Environmental Sciences, Babasaheb Bhimrao Ambedkar University, Lucknow, Uttar Pradesh, India

*Address all correspondence to: verma.02anita@gmail.com

References

[1] Sara P.B. Kamaludeen, Mallavarapu Megharaj, Albert L. Juhasz, Nabrattil Sethunathan, and Ravi Naidu *et. Al.*, from "Chromium–Microorganism Interactions in Soils: Remediation Implications(2003)",The University of Adelaide, Department of Soil and Water, Waite Campus, Glen Osmond, SA 5064, Australia and Tamil Nadu Agricultural University, Trichy Campus, Trichy, Tamil Nadu, India.

[2] Chaudhry F.N and Malik et.al.,from "Factors Affecting Water Pollution: A Review"(2017)Chaudhry FN, Department of Zoology, University of Gujrat, Hafiz Hayat Campus, Gujrat, Pakistan.

[3] Dr. Rajesh Kumar Mishra, Dr. Naseer Mohammad and Dr. N. Roychoudhury "Soil pollution: Causes, effects and control"Tropical Forest Research Institute P.O. RFRC, Mandla Road, Jabalpur (M.P.)– 482 021. India

[4] Mueller, E. et.al, The Effect of Acid Rain on Soil Nutrient Levels and Plant Growth.

[5] Tabatabai. M. Ali, Ames, Iowa et al, "Effect of acid rain on soils" Department of Agronomy Iowa State University.

[6] Albert L. Juhasz a,*, Euan Smith a , John Weber a , Matthew Rees b , Allan Rofe b , Tim Kuchel b , Lloyd Sansom c , Ravi Naidu et.al.,from "In vitro assessment of arsenic bioaccessibility in contaminated (anthropogenic and geogenic) soils"(2007).

[7] B.E. Johansen, The Dirty Dozen: Toxic Chemicals and the Earth's Future, Praeger Publishers, Westport, CT, 2003.

[8] Zaware Sandeep, et al, Environmental Impact Assessment on Soil Pollution Issue about Human, Health Department of Chemistry, Pacific Academy of Higher Education and Research University, Udaipur, Raj., INDIA

[9] Antonio Cristaldi a,b, *, Gea Oliveri Conti a , Eun Hea Jho c , Pietro Zuccarello a,b , Alfina Grasso a , Chiara Copat a , Margherita Ferrante et.al., from "Phytoremediation of contaminated soils by heavy metals and PAHs. A brief review".

[10] Hazrat Ali a,⇑ , Ezzat Khan and Muhammad Anwar Sajad et.al., from "Phytoremediation of heavy metals—Concepts and applications".

[11] Jim C. Philp and Ronald M. Atlas et. al., from "BIOREMEDIATION OF CONTAMINATED SOILS AND AQUIFERS".

[12] Gundula Prokop and Martin Schamann et.al.,from "Management of contaminated sites in Western Europe".

[13] EPA, (2003), Underground Storage Tanks. www.epa.gov/swerust1/ustsystm/erpdoc.pdf.

[14] M. Hyman, R. R. Dupont, Groundwater and Soil Remediation. Process Design and Cost Estimating of Proven Technologies, ASCE Press, 2001.

[15] C. J. Cunningham, J. C. Philip, Comparison of Bioaugmentation and Biostimulation in ex situ Treatment of Diesel Contaminated Soil, Land Contamination and Reclamation, University of Edinburgh, Scotland. 2000.

[16] Arpita Kulshreshtha, Ranu Agrawal, Manika Barar, Shilpi Saxena, "A Review on Bioremediation of Heavy Metals in Contaminated Water" Department of Chemistry, Jiwaji University, Gwalior (M.P.), India, Department of Chemistry, C.C.S. University, Meerut (U.P.), India

[17] Patrick Höhener and Violaine Ponsin et.al., from “In situ vadose zone bioremediation”.

[18] E. Gidarakos and M. Aivalioti et.al., from “Large scale and long term application of bioslurping: The case of a Greek petroleum refinery site”.

[19] Jila Baharlouei Yancheshmeh 1 *, Kazem khavazi 2 , Ebrahim Pazira 3 and Mahmood Solhi et.al.,from “Evaluation of inoculation of plant growth-promoting rhizobacteria on cadmium and lead uptake by canola and barley”.

[20] MARGESIN*, R., WALDER, G., SCHINNER, F.et.al.,from “Bioremediation Assessment of a BTEX-Contaminated Soil”.

[21] Irene Kuiper, Ellen L. Lagendijk, Guido V. Bloemberg, and Ben J. J. Lugtenberg et.al., from “Rhizoremediation: A Beneficial Plant-Microbe Interaction”.

[22] Nadeem Sarwar , Muhammad Imran, Muhammad Rashid Shaheen, Wajid Ishaq, Asif Kamran et.al., from “Phytoremediation strategies for soils contaminated with heavy metals: Modifications and future perspectives”.

[23] Abdul R. Memon &Peter Schröder et.al., from “Implications of metal accumulation mechanismsto phytoremediation’(2009).

[24] S. Dhanam et.al from “Strategies of Bioremediation of Heavy Metal Pollutants Toward Sustainable Agriculture” (2017).

[25] N. P. Singh , Jitendra Kumar Sharma , and Anita Rani Santal et.al.,from “Biotechnological Approaches to Remediate Soil and Water Using Plant–Microbe Interactions”(2015).

[26] P. Bulak, A. Walkiewicz, and M. Brzezinska et.al., from “Plant growth regulators-assisted phytoextraction” (2014).

[27] I.O..Fasidia, S.G. Jonathan, et.al. From “Biodegradation of Nigerian wood wastes by Pleurotus tuber-regium (Fries) Singer” (2008).