International Journal on Management Education & Emerging Technology
ISSN: 2583-9438

Biological Methods For Treatment And Monitoring Of Water And Soil Polluted By Hydrocarbons

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Abstract	Article Info
This paper provides an overview of biological methods for the treatment of oily water and soil, focusing on bioremediation, phytoremediation, and biologically activated carbon (BAC). Bioremediation utilizes microorganisms to degrade oil hydrocarbons, while phytoremediation employs plants to absorb and metabolize contaminants. BAC combines activated carbon filters with microbial biofilms to remove organic compounds. These methods offer cost-effective and sustainable alternatives to traditional remediation techniques. Factors influencing their efficacy include hydrocarbon concentration, environmental conditions, and species selection. Optimization and integration with complementary approaches enhance their performance. This review discusses principles, applications, advancements, challenges, and future research directions, highlighting the potential of biological methods to revolutionize oily water and soil remediation.	*Keywords:* Polluted water, soil, Bioremediation, Biological treatment.

Date of Submission: 05/01/2023
Date of Review: 25/02/2023

Date of Acceptance: 18/03/2023
IJMEET / Volume 1, Issue 1, 2023

INTRODUCTION

The presence of hydrocarbon content in water or soil cause many negative effect on health, safety, and environment [1]. The remediation of oily water and soil presents significant challenges due to the complex nature of oil hydrocarbon contaminants. Traditional methods often involve expensive and environmentally disruptive processes. In recent years, biological methods have gained attention as sustainable and cost-effective alternatives for the treatment of oily water and soil. This paper provides an overview of various biological methods employed in the treatment of oily water and soil, with a specific focus on bioremediation, phytoremediation, and biologically activated carbon (BAC).

Bioremediation involves the use of microorganisms to degrade oil hydrocarbons into less harmful compounds. It encompasses both in-situ and ex-situ approaches, utilizing naturally occurring or bioengineered microorganisms. Phytoremediation employs plants to uptake and metabolize contaminants through processes such as absorption, adsorption, and transformation. Different plant species have shown effectiveness in removing oil hydrocarbons from water and soil.

Biologically activated carbon (BAC) is a technique that utilizes activated carbon filters with a biofilm layer of microorganisms to remove organic contaminants, including oil hydrocarbons, from water. BAC combines the adsorption capabilities of activated carbon with the BDG potential of microorganisms, providing efficient and sustainable treatment.

These biological methods offer advantages such as lower costs, reduced environmental impact, and the potential for on-site treatment. However, their effectiveness is influenced by factors such as hydrocarbon concentration, environmental conditions, and microbial or plant species selection. Optimization of operational parameters and integration with complementary techniques can enhance their performance.

This paper reviews the principles, mechanisms, and applications of bioremediation, phytoremediation, and BAC for the treatment of oily water and soil. It also discusses recent advancements, challenges, and future research directions in the field. The adoption of these biological methods has the potential to revolutionize the remediation of oily water and soil, providing sustainable and eco-friendly solutions for addressing hydrocarbon contamination.

METHODS FOR BIOLOGICAL TREATMENT

These biological methods has specific applications and uses in environmental, agricultural, medical, and industrial contexts. They involve the use of microorganisms, plants, or other biological agents to perform specific functions related to remediation, treatment, waste management, and assessment.

Generally, biological treatment methods involve the use of plants or microorganisms, either individually or in combination, to treat various environmental contaminants. Plants and microorganisms have unique abilities to degrade, transform, or immobilize contaminants through their metabolic processes.

Plants can be used in phytoremediation, where they uptake contaminants from soil, water, or air through their roots or leaves. They can accumulate, metabolize, or store the contaminants, effectively reducing their concentrations in the environment. Different plant species have varying capabilities to remediate specific contaminants, making them suitable for different types of pollution.

Microorganisms play a crucial role in bioremediation, where they break down or transform contaminants into less harmful substances. They can degrade organic compounds, such as oil hydrocarbons or hazardous chemicals, through enzymatic reactions. Microorganisms can be naturally occurring or introduced through bioaugmentation, where specific strains are added to enhance the degradation capabilities.

In some cases, biological treatment methods may involve a combination of plants and microorganisms, such as in constructed wetlands, where plants provide physical support and create favorable conditions for microbial activity. Biologically activated carbon (BAC) filters also utilize microorganisms in conjunction with activated carbon to enhance the removal of organic contaminants.

These biological treatment methods offer several advantages, including sustainability, low energy requirements, and potential cost-effectiveness compared to conventional treatment approaches. However, their efficacy depends on factors such as the type of contaminant, environmental conditions, and the specific plant or microbial species used.

These methods can be used alone or in combination with other physical and chemical remediation techniques to provide a comprehensive solution to pollution problemsby water and soil. The choice of method(s) used will depend on various factors such as the type and extent of contamination, site conditions, and regulatory requirements.
There are various biological methods for treatment of water such as bioremediation, constructed wetlands, biological nutrient removal (BNR), microbial fuel cells (MFCs). Bioremediation has many types such as biodegradation, phytoremediation, bioaugmentation, biostimulation, microbial remediation, Mycoremediation. The methods for agriculture and waste management are composting, vermicomposting, anaerobic digestion.

Treatment Agents

The main agents commonly used in various biological treatment methods are plants, microorganisms, algae, and enzymes. These agents play important roles in different aspects of bioremediation and environmental treatment processes. Here's a brief overview:
Plants: Plants, including certain species of trees, grasses, and flowering plants, are commonly used in phytoremediation. They have the ability to uptake, stabilize, or transform contaminants from soil, water, or air through processes such as phytoextraction, phytodegradation, phytostabilization, or rhizofiltration.
Microorganisms: Microorganisms, including bacteria, fungi, and bacterial consortia, are widely employed in bioremediation. They possess the enzymatic capabilities to degrade or transform various contaminants, breaking them down into less harmful forms. Microorganisms are used in processes such as biodegradation, biosorption, or bioaugmentation. Specific combinations of bacterial strains or species can be used in water treatment to enhance the degradation of contaminants. These bacterial consortia may be tailored for particular pollutants, such as hydrocarbons or organic compounds, and can be applied in bioreactors or biofiltration systems.
Algae: While not classified as microorganisms, algae are photosynthetic organisms that can be utilized in water treatment and environmental applications. They can contribute to nutrient removal, organic matter degradation, and the removal of contaminants through processes like adsorption, bioaccumulation, or nutrient uptake. They can be utilized in various water treatment processes, particularly for nutrient removal. They can effectively remove nitrogen and phosphorus from wastewater through processes like assimilation and adsorption, reducing the impact of eutrophication.
Enzymes: Enzymes are biological catalysts that can be derived from microorganisms, plants, or produced through biotechnology. Enzyme-based methods are used to accelerate chemical reactions and breakdown complex molecules, facilitating the degradation or transformation of contaminants in water, soil, or other environmental matrices. They can be used in water treatment to enhance the degradation or transformation of specific contaminants. For example, enzymes like lipases or cellulases can break down oils or organic compounds, while peroxidases can assist in the breakdown of certain pollutants.

These agents, either individually or in combination, form the foundation of biological treatment methods and offer sustainable and environmentally friendly approaches for remediation and purification processes.

Table 1. The various types of treatment of water and soil.

Agent	Principle of work
Plants	Phytoremedition
Microorganisms	Bioremediation
Algae	Phytoremedition
Enzymes	Biocatalyst

The selection and application of these biological agents in water treatment depend on the specific contaminants, treatment objectives, and operational conditions. It is important to consider factors such as compatibility, effectiveness, and feasibility when incorporating these agents into water treatment processes.

2. General Application for water and soil

2.1 Phytoremediation

Cleaning water using plants is a process known as phytoremediation. Phytoremediation involves using plants to absorb and metabolize contaminants in the water. Some plants have the ability to absorb and break down hydrocarbons, making them effective in treating oily water.Phytoremediation is a natural, cost-effective and sustainable method of removing contaminants from soil, water, and air. Plants have the ability to absorb, metabolize, and detoxify various pollutants from the environment. Through their roots, plants can absorb contaminants such as heavy metals, organic compounds, and nutrients from the soil or water. These contaminants are then metabolized and transformed into less harmful substances by the plant's enzymes and microorganisms present in the rhizosphere (the soil surrounding the roots).

Phytoremediation can be used to treat various types of water bodies such as rivers, lakes, ponds, and even wastewater. Different types of plants can be used for phytoremediation, depending on the type and concentration of the contaminants present in the water. For example, plants such as water hyacinth, duckweed, and water lettuce are commonly used to treat wastewater, while cattails and bulrushes are used to treat contaminated surface water.

Overall, phytoremediation is an environmentally friendly and sustainable approach to water treatment that can be used in conjunction with other treatment methods to provide an effective solution to water pollution. There are several plant species that have been found to be effective in removing oil hydrocarbons from water in phytoremediation studies. Here are a few examples:

1. Sunflowers - Sunflowers have been found to be effective in removing heavy metals and organic contaminants, including oil hydrocarbons, from contaminated water.
2. Cattails - Cattails are commonly used in wetland restoration projects and have been found to be effective in removing oil hydrocarbons from water.
3. Duckweed - Duckweed is a floating aquatic plant that can grow quickly and absorb large amounts of nutrients and pollutants, including oil hydrocarbons.
4. Water hyacinth - Water hyacinth is a fast-growing floating plant that can absorb nutrients and pollutants, including oil hydrocarbons, from water.
5. Reed Canarygrass - Reed canarygrass is a perennial grass that can be used in constructed wetlands to treat contaminated water. It has been found to be effective in removing oil hydrocarbons from water.
   - Algal treatment - It can be called algae-based treatment. algae can be used in the treatment of soil as well. Algae-based treatments can help improve soil quality and address certain soil-related issues. Here are a few ways in which algae can be utilized in soil treatment:
   - Soil fertility and nutrient enrichment: Algae can contribute to soil fertility by fixing atmospheric nitrogen and making it available to plants. Some algae species have the ability to form symbiotic relationships with plants, called mutualistic associations, where they provide nutrients to the plants in exchange for a suitable environment. Algae can also release organic compounds and exudates that improve soil structure and nutrient availability.
   - Soil erosion control: Algae can be used as a ground cover or as part of erosion control measures to stabilize soils. Algal mats or biofilms can bind soil particles together, reducing erosion caused by wind or water.
   - Organic matter decomposition: Algae, along with other microorganisms, participate in the decomposition of organic matter in the soil. They break down dead plant material and organic residues, contributing to nutrient cycling and soil organic matter formation.
   - Phytoremediation: Certain types of algae have the ability to absorb or accumulate heavy metals and other contaminants from the soil. They can be used in phytoremediation processes to assist in the removal or sequestration of pollutants from contaminated soils.

By incorporating algae into soil treatment strategies, it is possible to enhance soil fertility, control erosion, facilitate organic matter decomposition, and aid in the remediation of contaminated soils. Algae's ability to perform photosynthesis and their interactions with soil microorganisms make them valuable contributors to soil health and improvement.

It's worth noting that the effectiveness of phytoremediation varies depending on the type and concentration of contaminants present in the water, as well as the environmental conditions. Therefore, it's important to carefully select the appropriate plant species and monitoring their growth and effectiveness in removing contaminants from the water.

Phytoremediation of soil involves using plants to absorb and metabolize contaminants in the soil. Some plants have the ability to absorb and break down specific contaminants, such as heavy metals. This method is effective for treating contaminated soil, but it is not typically used for treating water.

Bioremediation.

There are many attempts in studying the phytoremediation of polluted water and soil using cotton such as [2.3] and some papers compared among various agents such as alfalfa, cotton, grass [4]. Al-Tameemi studied the phytoremediation by Acacia farnesiana L. Willd. and Spraying Glutathione [5].

2.2 Bioremediation

There are many types of bioremediation as following:

Biodegradation (BDG): BDG is a process that can be used to remove oil hydrocarbons from water. BDG is the process by which microorganisms break down and metabolize organic compounds such as oil hydrocarbons into simpler compounds such as carbon dioxide and water.

Bioaugmentation: This involves the introduction of microorganisms or enzymes to contaminated soil or water to enhance the rate of degradation or detoxification of pollutants. Bioaugmentation involves adding specific strains of microorganisms to the water to enhance the breakdown of hydrocarbons. This method is often used when the natural microbial populations in the water are not sufficient to effectively break down the contaminants.

1. Bioaugmentation of soil involves adding specific strains of microorganisms to the soil to enhance the breakdown of hydrocarbons.
2. Biostimulation: This involves the addition of nutrients, electron acceptors, or other naturally occurring growth-promoting substances to contaminated soil or water to stimulate the growth of indigenous microorganisms that can degrade or transform pollutants hydrocarbons. In the case of oily water, the microorganisms can break down the oil and other contaminants..
3. Biostimulation of soil involves adding nutrients to the soil to promote the growth of naturally occurring microorganisms that can break down hydrocarbons.
4. Microbial remediation: This involves the use of genetically engineered microorganisms to degrade or transform specific contaminants.
5. Mycoremediation: It can be called fungal treatment. This involves the use of fungi to degrade or transform pollutants, particularly in soil or other solid matrices. Certain fungi, such as white rot fungi, have the ability to degrade recalcitrant organic compounds, including pesticides and industrial pollutants, in water. They can be employed in bioreactors or biofilters to treat contaminated water.
6. Composting: This involves the use of controlled biological decomposition of organic matter to degrade contaminants in organic waste.
7. Composting of soil involves mixing contaminated soil with organic matter and allowing it to decompose over time. The microorganisms responsible for decomposition can also break down hydrocarbons. It involves mixing contaminated soil with organic matter and allowing it to decompose over time. The microorganisms responsible for decomposition can also break down contaminants, such as hydrocarbons. This method is effective for treating soil contaminated with organic pollutants, but it is not typically used for treating water.

There are many attempt to study the bioremediation of oily water or soil such as [6], Hussein studied the bioremediation of wastewater by using Bacillus [7]. While Jabbar stidied the bioremediation of diesel-polluted soil by using biopiles system [8] and Nafal studied the polluted soil by Consortium bacteria [9].

2.3 Biocatalytic Remediation

Also, its known as enzyme-assisted remediation, it refers to a remediation approach that utilizes enzymes to enhance the degradation or transformation of contaminants in soil. Enzymes are biological catalysts that can accelerate chemical reactions, making them valuable tools for breaking down complex molecules into simpler, less harmful forms.

In enzyme-assisted soil remediation, specific enzymes are applied to contaminated soil to target and facilitate the breakdown of contaminants. The enzymes used are typically derived from microorganisms, plants, or produced through biotechnological processes. These enzymes possess specific activities that enable them to degrade or transform specific classes of contaminants, such as hydrocarbons, pesticides, or organic pollutants. The process of enzyme-assisted soil remediation typically involves the following steps:

- Contaminant Analysis: The contaminated soil is assessed to determine the types and concentrations of contaminants present. This information helps in selecting the appropriate enzymes for the remediation process.
- Enzyme Selection: Specific enzymes are chosen based on their compatibility with the target contaminants. Different enzymes may be required to address different classes of pollutants present in the soil.
- Enzyme Application: The selected enzymes are applied to the contaminated soil. This can be done through various methods, such as spraying, injection, or incorporation into the soil matrix.
- Contaminant Degradation: The enzymes catalyze the breakdown or transformation of the contaminants present in the soil, converting them into less toxic or more easily remediated forms. This enzymatic degradation process helps to reduce the concentration and potential toxicity of the contaminants.
- Enzyme-assisted soil remediation can be used as a standalone technique or in combination with other remediation methods, such as phytoremediation or bioremediation. By utilizing the unique capabilities of enzymes, this approach offers the potential to enhance the efficiency and effectiveness of soil remediation efforts, particularly for complex or recalcitrant contaminants.

2.4 Combined Methods

Biologically activated carbon (BAC): BAC involves using activated carbon filters with a layer of microorganisms to remove organic contaminants from water. The microorganisms break down the organic compounds, while the activated carbon helps to remove any remaining contaminants.

- Constructed wetlands: Constructed wetlands are designed systems that mimic natural wetlands to treat wastewater. Plants and microorganisms work together to remove pollutants through processes such as adsorption, absorption, and microbial degradation. Constructed Wetlands with Microorganisms: Constructed wetlands are engineered systems that mimic natural wetlands and utilize a combination of physical, chemical, and biological processes to treat water. In these systems, plants (phytoremediation) are combined with microorganisms (bioremediation) present in the wetland soil and root zone. The plants help to facilitate oxygen transfer and provide a surface for microbial colonization, while the microorganisms assist in the breakdown and removal of contaminants.
- Biological nutrient removal (BNR): BNR is a process that removes nitrogen and phosphorus from wastewater using a combination of microorganisms and chemical precipitation. The microorganisms break down the organic matter in the wastewater, converting nitrogen to gas and removing phosphorus through biological uptake.
- Microbial fuel cells (MFCs): MFCs use bacteria to break down organic matter in wastewater, generating electricity as a byproduct. The process can help to treat the water while also producing renewable energy.
- Bioaugmentation with Solid Sorbents: Bioaugmentation involves introducing specific microbial cultures or consortia to enhance bioremediation capabilities. In some cases, bioaugmentation can be combined with the use of solid sorbents, such as activated carbon or other adsorbent materials. The sorbents serve as physical media to capture and concentrate contaminants, while the introduced microorganisms help to biodegrade the captured contaminants.
- Enzyme-Assisted Phytoremediation: This approach combines the use of plants (phytoremediation) with the application of enzymes to enhance the degradation of specific contaminants. Enzymes can be applied directly to the plant roots or incorporated into the soil, promoting the breakdown of targeted pollutants. This integrated method leverages both the natural capabilities of plants and the catalytic power of enzymes for effective remediation.

These combined methods demonstrate the potential for synergistic effects, where different remediation approaches work together to achieve more comprehensive and efficient treatment. By integrating physical, chemical, and biological processes, these methods can address a wider range of contaminants and provide more effective remediation outcomes than individual techniques alone.

These biological methods can be used alone or in combination with physical and chemical treatment methods to provide a comprehensive solution to water treatment. The choice of method(s) used will depend on various factors such as the type and extent of contamination, site conditions, and regulatory requirements.

3. Special applications for water treatment

Here are some biological methods that can be used for treating oily water:

- Bioreactors: These are systems that use microorganisms to break down contaminants in the water. In the case of oily water, bioreactors can be used to remove oil and other hydrocarbons from the water.
- Rhizofiltration: This involves using plants with deep root systems to absorb contaminants from the water. In the case of oily water, plants such as willows and poplars can absorb hydrocarbons through their roots. It involves using plants to filter out contaminants from contaminated water. The plant roots absorb the pollutants, and then the cleaned water is released back into the environment. This technique is often used for organic pollutants such as pesticides and herbicides. This involves using plants with deep root systems to absorb contaminants from the soil. In the case of oily soil, plants such as willows and poplars can absorb hydrocarbons through their roots.

Overall, phytoremediation is a cost-effective and environmentally friendly approach to soil cleaning, but its effectiveness depends on the type of contaminant, the site conditions, and the plant species used.

- Biofiltration: This involves passing contaminated water through a filter containing microbial populations that can break down the contaminants. In the case of oily water, biofilters can be used to remove oil and other hydrocarbons from the water.

Overall, while some of the biological methods used for treating oily soil and oily water may be the same, there are some differences in application and effectiveness depending on the specific conditions of the contaminated site.

4. Special Applications for Soil Treatment

Biological methods for treating oily soil typically fall into two broad categories: bioremediation and phytoremediation. Bioremediation involves the use of microorganisms to break down contaminants in the soil. This can be achieved through natural attenuation or by adding specific microorganisms to the soil. In the case of oily soil, the microorganisms can break down hydrocarbons, which are the main component of petroleum products. Phytoremediation involves the use of plants to absorb and metabolize contaminants in the soil. Some plants have the ability to absorb and break down hydrocarbons, making them effective in treating oily soil.

Plants have the ability to absorb and break down certain contaminants in the soil through a process called phytoremediation. This process involves the uptake of pollutants by the plant roots, and then the plant metabolizes or stores the contaminants in its tissues. This can effectively remove or reduce the levels of contaminants in the soil. There are different types of phytoremediation techniques, such as phytoextraction, phytostabilization, phytovolatilization, and rhizofiltration. Each technique uses different types of plants and mechanisms to target specific contaminants in the soil.

4.1 Phytoextraction

It involves using plants that can accumulate high levels of contaminants in their tissues, which are then harvested and disposed of. This technique is often used for heavy metals such as lead, zinc, and cadmium. This involves using plants to absorb contaminants from the soil. In the case of oily soil, plants such as sunflowers, Indian mustard, and alfalfa can absorb hydrocarbons and break them down.

4.2 Phytostabilization

It uses plants to immobilize contaminants in the soil, preventing them from spreading and becoming airborne or entering groundwater. This technique is often used for contaminated sites with low to moderate levels of pollutants. This involves using plants to immobilize contaminants in the soil, preventing them from spreading. In the case of oily soil, plants such as switchgrass and tall fescue can help to stabilize the soil and prevent the spread of hydrocarbons.

4.3 Phytovolatilization

It involves using plants to absorb contaminants from the soil and then release them into the air through their leaves. This technique is often used for volatile organic compounds (VOCs) such as benzene and trichloroethylene.

4.4 Landfarming

This involves spreading contaminated soil over a large area and incorporating nutrients to promote the growth of microorganisms that can break down contaminants, such as hydrocarbons the hydrocarbons. This method is effective for treating oily soil, but it cannot be used for treating oily water.

The bioremideiation methods are aforementioned general application.

5. Methods for Monitoring

There some methods can be relevated in environmental monitoring and assessment such as biomonitors, bioindicators, bioreporters.

6. Pollution of air by air

Due to th incomplete combustion of fuels or natural gas, methane emissions are produced to the atmosphere [10]. Air pollution resulting from the emission of methane poses a significant environmental and health concern. Methane is a potent greenhouse gas, with a much higher heat-trapping capacity than carbon dioxide. It is released into the atmosphere through various human activities, including the extraction and transport of fossil fuels,

livestock farming, waste management, and natural gas leaks. Methane emissions contribute to climate change, exacerbating global warming and altering weather patterns. Furthermore, methane is also associated with the formation of ground-level ozone, a harmful air pollutant that negatively affects human health and ecosystems. High levels of methane in the atmosphere contribute to the degradation of air quality and pose risks to respiratory health, as well as contribute to the formation of smog. Addressing methane emissions is crucial for mitigating climate change and improving air quality. Implementing measures to reduce methane emissions, such as improving leak detection and repair in the fossil fuel industry, implementing better waste management practices, and promoting sustainable agricultural practices, are vital steps toward reducing the impact of methane pollution on our environment and human well-being.

7. Aplicability of Treatment Methods

For phytoremediation, the range of concentrations that plants can effectively remove oil hydrocarbons from water varies depending on the specific plant species and the environmental conditions. Generally, plants can be effective in removing oil hydrocarbons from water at relatively low concentrations. For example, in laboratory studies, sunflowers have been found to remove up to 90% of oil hydrocarbons from water at concentrations of 10-100 mg/L. Cattails have been found to be effective in removing oil hydrocarbons at concentrations of up to 3,000 mg/L. Duckweed has been found to be effective in removing oil hydrocarbons at concentrations of up to 10,000 mg/l.

However, it's important to note that the effectiveness of phytoremediation depends on many factors, including the type and concentration of contaminants present, the environmental conditions, and the specific plant species being used. Additionally, phytoremediation is typically used in combination with other treatment methods to provide a comprehensive solution to water pollution.

8. Analysis of Mechanism and Response

In phytoremediation, when plants remove oil hydrocarbons from water, the hydrocarbons are taken up by the plant's roots and transported to the aerial parts of the plant, where they can be metabolized and transformed into less harmful substances by the plant's enzymes and microorganisms present in the rhizosphere. The hydrocarbons are broken down into simpler compounds such as carbon dioxide, water, and other organic molecules. In some cases, the hydrocarbons may also be stored in the plant's tissues, such as in the leaves or stems, depending on the specific plant species and the type of hydrocarbon. The hydrocarbons can then be harvested and disposed of properly or used for other purposes, such as energy production.

It's important to note that the effectiveness of phytoremediation in removing oil hydrocarbons from water depends on many factors, including the specific plant species being used, the concentration and type of hydrocarbon, and the environmental conditions. Additionally, phytoremediation is often used in combination with other treatment methods to provide a comprehensive solution to water pollution.

The rate of removing oil hydrocarbons from water using phytoremediation depends on various factors, such as the type and concentration of the hydrocarbons present in the water, the specific plant species being used, and the environmental conditions. In general, the rate of oil hydrocarbon removal through phytoremediation is typically slower than traditional remediation methods such as pumping and treating contaminated water or soil. However, phytoremediation can be more cost-effective and sustainable over the long term.

The rate of oil hydrocarbon removal by plants can also vary depending on the growth and biomass of the plant. Generally, faster-growing plants with more biomass are able to remove contaminants at a faster rate. The specific rate of removal will depend on the specific plant species, the hydrocarbon concentration, and other environmental factors. Overall, the effectiveness of phytoremediation depends on a variety of factors, and it is often used in combination with other remediation methods to provide a comprehensive solution to water pollution.

Most of the biological methods used for treating oily soil can also be used for treating oily water, but the application and effectiveness may vary depending on the specific conditions.

- Enzymes are biological catalysts that accelerate chemical reactions by binding to specific substrates and facilitating their transformation into different products. Enzymes used in environmental treatment are typically derived from microorganisms, plants, or produced through biotechnological processes. They possess specific enzymatic activities that target particular contaminants or classes of compounds. The enzymes used in remediation processes are selected based on their ability to break down or transform the targeted contaminants into less harmful forms. Enzymatic remediation typically involves the following steps:
- Enzyme Selection: Specific enzymes are chosen based on their ability to degrade or transform the target contaminants of concern. Different enzymes may be used for different classes of compounds, such as hydrocarbons, pesticides, or organic pollutants.
- Enzyme Production: Enzymes can be produced through microbial fermentation or through biotechnological methods. They can be obtained from natural sources or engineered through genetic modification to enhance their activity or stability.
- Enzyme Application: The enzymes are applied to the contaminated site or introduced into the treatment system. They can be added directly to soil, water, or other matrices containing the contaminants.
- Contaminant Degradation: The enzymes catalyze the breakdown or transformation of the contaminants, converting them into less toxic or more easily remediated forms. This enzymatic degradation process often results in the breakdown of complex molecules into simpler, non-hazardous compounds.

Enzymatic remediation offers several advantages, including high specificity, efficiency, and the ability to target specific contaminants. It can be used in conjunction with other biological treatment methods or as a standalone approach, depending on the specific remediation needs. Overall, the principle of work for enzymes in environmental treatment involves the use of specific enzymes to catalyze the degradation or transformation of contaminants, leading to their remediation and the improvement of environmental quality.

Here are the key aspects of how algae work in environmental treatment:

- Nutrient Uptake: Algae have the ability to absorb and utilize nutrients, such as nitrogen and phosphorus, from their surrounding environment. This nutrient uptake helps in reducing nutrient concentrations in water bodies, mitigating issues like eutrophication, and improving water quality.
- Photosynthesis: Algae are photosynthetic organisms, meaning they can use sunlight, carbon dioxide, and nutrients to produce organic matter and release oxygen as a byproduct. Through photosynthesis, algae can contribute to the oxygenation of water bodies, enhancing the overall health of aquatic ecosystems.
- Contaminant Absorption and Bioaccumulation: Some species of algae have the capability to absorb or accumulate contaminants, including heavy metals and organic pollutants, from their environment. This process is known as biosorption or bioaccumulation. Algae can bind with contaminants, effectively removing them from the surrounding medium.

- Organic Matter Degradation: Algae, along with other microorganisms, participate in the decomposition of organic matter in water and soil. They contribute to the breakdown of dead plant material, organic residues, and other organic compounds, helping in nutrient cycling and overall organic matter degradation.
- Algal Filtration and Clarification: Algae, particularly certain types of filamentous algae or microalgae, can form dense mats or biofilms that act as filters, trapping suspended particles and clarifying water. This filtration process helps in reducing turbidity and improving water clarity.
- By harnessing these natural capabilities, algae can play a significant role in the treatment of water, soil, and air. Algae-based treatment methods can include techniques such as algae ponds, bioreactors, constructed wetlands, or algal biofilms, where algae are strategically employed to address specific environmental challenges and improve the quality of the ecosystem.

The rate of BDG depends on several factors, such as the type and concentration of hydrocarbons present in the water, the temperature, the pH, the availability of nutrients, and the presence of microorganisms capable of degrading the hydrocarbons. BDG can be enhanced through biostimulation, which involves adding nutrients or other substances to the contaminated water to promote the growth of hydrocarbon-degrading microorganisms. Another technique is bioaugmentation, which involves adding specific strains of microorganisms to the contaminated water to enhance the BDG process. The rate of BDG is typically faster than phytoremediation but may require more intensive monitoring and maintenance to ensure that the conditions for BDG are optimized. BDG is often used in combination with other remediation methods such as phytoremediation or pump-and-treat methods to provide a comprehensive solution to water pollution.

CONCLUSION

Biological treatment methods, including phytoremediation, bioremediation, and enzymatic (biocatalyst) methods, offer effective and environmentally friendly approaches for the remediation of contaminated sites. Phytoremediation utilizes the natural abilities of plants to absorb, accumulate, and degrade contaminants, with notable examples including sunflowers for heavy metal uptake and water hyacinths for nutrient removal. Bioremediation harnesses the power of microorganisms to degrade or transform contaminants, such as bacteria breaking down petroleum hydrocarbons or fungi degrading wood preservatives. Enzymatic methods, employing specific enzymes, enhance the degradation or transformation of contaminants in soil or water, with applications ranging from enzymatic degradation of pesticides to enzymatic oxidation of pollutants. These biological treatment methods provide versatile and sustainable approaches for the remediation of various contaminants, showcasing the potential of living organisms and their interactions with the environment to restore contaminated sites and promote environmental health.

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