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Application and Prospect of Soil Microorganisms in Agro-ecological Environment

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Abstract

Sustainable agriculture has also received increasing attention in recent years. In the pollution of the agro-ecological environment, pollution sources such as oil, pesticides and heavy metals are seriously affecting the soil. These pollution will not only reduce food production and poor crop growth, but also greatly affect the soil environment, which will cause major losses to agriculture in the long run. Among the many methods for soil environment remediation, microbial remediation is the most promising bioremediation technology with development and application potential. In this paper, the application types, influencing factors and mechanisms of microorganisms in the restoration of petroleum, heavy metal and pesticide pollution, as well as the development status of microbial remediation technology and its application prospect in agricultural ecological environment are reviewed.

Keywords

Soil; Microbe; Contaminate; Degradation; Petroleum Hydrocarbons; Heavy Metal.

1. Introduction

Sustainable agriculture Today's society is the primary requirement for agriculture. Because it can not only make full use of environmental resources, but also ensure that it does not cause any harm, ensuring the safety and health of agricultural products. Soil microorganisms determine the basic properties of soil to a certain extent, and play an important role in soil fertility and nutrient delivery [1]. Microorganisms play an indispensable role in the material cycle as decomposers in ecosystems. They can degrade and transform almost all natural substances in the environment, and even if new substances appear, microorganisms can induce and mutate to produce new ways to degrade this substance. In other words, as long as microorganisms are under suitable growth conditions, most soil pollutants in the agricultural environment can be degraded and transformed to a certain extent [2].

2. Pollution Factors of Agricultural Ecological Environment

2.1. Oil Pollution

The transportation and processing of oil will cause different degrees of soil and water pollution. Benzene substances and polycyclic aromatic hydrocarbons in petroleum have carcinogenic, teratogenic, mutagenic triple effects, such substances in food crops for a long time, through the food chain transmission into the human body, will seriously affect human health, and even endanger life [3]. Petroleum hydrocarbons are one of the main forms of oil in soil pollution, mainly composed of carbon, hydrogen, oxygen and some trace elements. The main methods for remediating petroleum hydrocarbon pollution are: physical remediation, chemical remediation, bioremediation, and a combination of various remediation technologies. In the remediation of oil-contaminated soil, microbial remediation is considered to be safe, environmentally friendly,

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cost-saving, no secondary pollution, and the most in line with the requirements of sustainable agriculture [4].

2.1.1. Microorganisms that Degrade Petroleum Hydrocarbons

At present, it has been found that microorganisms such as bacteria, actinomycetes, and fungi that can degrade petroleum hydrocarbons can degrade petroleum hydrocarbons. It is generally believed that the relative ability to degrade crude oil is bacteria> fungi and actinomycetes [6]; The degradation effect is fungi > bacteria, while the degradation ability of algae and protozoa is less significant. The bacteria that degrade petroleum hydrocarbons more are pseudomonas, which can degrade alkanes and aromatic hydrocarbons well; The most studied actinomycetes are Nocardia species; The most widely used fungus is Candida, which has low nutritional requirements, fast growth and reproduction and significant degradation effect [6]. Studies have proved that the synergy of a variety of different microorganisms can degrade petroleum more completely.

2.1.2. Microbial Remediation Mechanisms for Oil-contaminated Soils

Oil pollutants are used as nutrients by microorganisms to be absorbed into other organic components, and the rest are oxidized and decomposed into simple organic or inorganic substances, such as methane, water, carbon dioxide. For different hydrocarbons in oil, microorganisms have different metabolic pathways [7].

The presence of branched chains hinders the process of oxidative decomposition of microorganisms. The ring number, solubility, number of substituents, type and location of polycyclic aromatic hydrocarbons determine the degree of degradation by microorganisms.

Simple petroleum pollutants are not easy or cannot be directly used by microorganisms, and some irritating substances need to be added to improve the ability of microorganisms to degrade petroleum hydrocarbons [8]. Adding nutrients to contaminated soil strengthens the metabolism of microorganisms, which in turn enhances their ability to degrade pollutants; Introduction of air and electrical stimulation can change the properties of cell membranes, enhance the contact between microorganisms and pollutants, and increase metabolic rate; The addition of surfactants and activators can improve the degradation ability of microorganisms; The addition of inorganic irritants increases soil biomass. Bioaugmentation is a technology that inoculates highly efficient degrading bacteria after domestication into contaminated soil, and can significantly promote petroleum degradation by optimizing the microbial environment [10]. This technology has the characteristics of strong adaptability of strains, has obvious effect on petroleum degradation, and can overcome the limitations of biostimulation technology. The technology is divided into direct sterilization method, combination of bacteria and nutrients, soil turning and conditioning agent. However, it is easily affected by soil physical and chemical properties and environmental conditions, and its application is also limited.

2.2. Heavy Metal Pollution

Soil heavy metal pollution refers to the phenomenon that due to human activities, the heavy metal content is significantly higher than the original content, and the environmental quality is deteriorated [11]. Low concentrations of heavy metals can stimulate the growth of soil microorganisms, and high concentrations of heavy metals will significantly reduce the biomass of microorganisms in soil through microbial growth metabolism. However, some heavy metals are highly toxic at low concentrations. For example, mercury has a mutagenic effect on microorganisms, terminates cell division activities through the synthesis of nucleic acids and protein biological macromolecules, and inhibits biological oxidation; Lead disrupts the transport of cellular nutrients by disrupting cell membranes; Cadmium breaks the DNA chain and also has a mutagenic effect. The study found that when the concentration of cadmium in soil was 0.2mg/L, the reproduction of anaerobic nitrogen-fixing bacteria was completely

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inhibited. When the mass concentration of cadmium was 0.5mg/L, the nitrogenase activity of anaerobic nitrogen-fixing bacteria was completely inhibited [11].

2.2.1. Mechanisms of Microbial Remediation of Heavy Metal Contaminated Soil

In the face of the selective effect of heavy metal pollution for a long time, microorganisms continue to evolve and mutate, constantly enhancing their resistance, resistance to heavy metals and highly selective. Adapt to increasing contamination through various metabolic activities, redox reactions, enzymatic reactions, and other mechanisms[12].

Microorganisms themselves and their products can adsorb and convert heavy metals. Such as cyanobacteria, sulfate-reducing bacteria and some algae, extracellular polymers with a large number of anionic groups are produced by extracellular complexation and combined with metal ions; Some long-term exposure to rotting wood fungi containing metal preservatives produces metabolites with detoxic toxicity, such as citric acid, which is a metal chelating agent; oxalic acid, combined with metals to form oxalate precipitation; Some cells with anti-heavy metal genes secrete substances that deposit or excrete heavy metals out of the cell[13]. At present, it has been found that the cells of lead and zinc resistance contain anti-heavy metal genes; Some microorganisms can reduce the toxicity and mobility of heavy metal ions through redox action. The hexavalent state of chromium is more toxic than the trivalent state, so microorganisms can reduce $Cr6+$ to $Cr3+$ to reduce toxicity. Or reduce heavy metals to a soluble, volatile state. For example, the poorly soluble $Pu4+$ is reduced to $Pu3+$, and $Hg2+$ is reduced to volatile Hg; Some microorganisms can also form corresponding resistance mechanisms such as intracellular isolation mechanisms, membrane mechanisms, and resistance plasmids to form detoxification mechanisms for heavy metals[14]. Plant roots and root secretions can provide a growth environment and nutrient source for microorganisms with degradability, and if exogenous nutrients can be added to improve this condition, the ability of microorganisms to degrade pollutants will be improved. The technology of using the mutually beneficial symbiotic relationship between plants and microorganisms to enhance the metabolic decomposition of pollutants in the plant rhizosphere is called plant-microbial joint restoration technology[15].

The above-mentioned microorganisms reduce the degree of pollution of heavy metals in the agricultural environment, and have great application potential.

3. Development Status of Remediation Technology for Contaminated Soil

Compared with physical remediation and chemical remediation, bioremediation has the characteristics of low cost, no damage to the soil environment, and no secondary pollution. Microbial remediation is a bioremediation method that uses indigenous microorganisms in the soil or exogenous microorganisms that have an efficient degrading effect on soil supplementation to remediate contaminated soil [17]. The use of energy by microorganisms is more effective than that of higher organisms, and has the characteristics of rapid reproduction and genetic variability, so that it can adapt to changes in the external environment at the fastest speed, thus showing its efficiency and diversity in environmental governance. Bioremediation methods are divided into in situ bioremediation technology and ectopic bioremediation technology according to the repair site

3.1. In Situ Repair Technology

In situ bioremediation technology is a remediation technology that directly remediates contaminated soil in situ at contaminated sites without displacing contaminated soil, and there are three main methods: (1) biological culture method, also known as biological stimulation method, and the source of the strain is indigenous microorganisms. Regularly add additives such as nutrients, electron acceptors and surfactants to contaminated soil to improve the reproduction and activity of indigenous microorganisms, thereby improving their degradation

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capacity; (2) Biofortification method, also known as the injection method, is usually domesticated bacteria or genetically engineered bacteria with high degradation ability, and provides sufficient nutrients for them; (3) The biological aeration method is to introduce air into the contaminated soil block, so that the volatile pollutants in the soil are effectively removed, which is conducive to improving the degradation activity of degrading bacteria in the soil[18].

3.2. Extopic Repair Techniques

Ex-situ remediation technology refers to the remediation technology that excavates contaminated soil from the original place and transports it to a designated place for disposal, which is efficient and convenient for monitoring. However, the engineering volume is large, the operation is complex, and the cost is high. This remediation technique is now a common method for treating contaminated soil. There are three main methods: (1) Bioreactor method: it is to dig out the soil that needs to be remediated and remove the stones in it, disperse it in water, and then send it to the reactor device for inoculating microorganisms for treatment. Add nutrients, control the temperature, and mix well to ensure the optimal conditions for the growth of microorganisms and maximize their degradation capacity. Once the treatment target is reached, the dewatering is filtered and the soil is transported back to its original location. (2) Soil composting method: dig out the contaminated soil and put it in an aerobic environment, and add agricultural waste, such as: leaves, wheat straw, wood chips, manure, etc. And use lime to adjust pH, so that oxygen, moisture and pH can reach the most suitable conditions, improve its metabolism and activity, and promote the degradation of petroleum pollutants. (3) Prefabricated bed method: set up a platform that can prevent leakage, spread stones and sand with a thickness of 10-30cm on the treatment mat, put in appropriate nutrients and water, and turn it regularly to make the soil fully contact with nutrients and air. The liquid that leached during the treatment process can be re-added to the soil, so that the pollutants in the target soil can be effectively degraded. (4) Soil tillage method: transfer the soil to be repaired to the treatment mat on the soil tillage site and turn it regularly. Low cost and short time, but cannot handle volatile organic compounds. (5) Biological pile method: It is an improved form of soil cultivation method, on the basis of soil cultivation method, anti-leakage substrate, ventilation pipe, etc. are set up for soil cultivation sites. The technical design and installation are simple, the repair time is short, but the footprint is large [19].

4. Prospects

Agriculture is the foundation of a country, but a series of pollution problems left over from the past such as the excessive pursuit of yield and value, weak environmental supervision, and irregular markets have hindered soil remediation. In line with the tenets of green development and building an environmentally-friendly society, microorganisms have unlimited potential in rehabilitating the agricultural environment. Microorganisms have the characteristics of absorption, fast transformation, vigorous growth, fast reproduction, strong adaptation, easy mutation, wide distribution and variety, and are one of the most precious and potential resource banks for human beings. However, due to the complex types and properties of pollutants in soil, it is difficult for soil remediation to show obvious results under a single remediation pathway, and the construction of genetically engineered bacteria provides a new way to solve this problem. At the same time, comprehensive restoration technologies such as the combination of multiple repair technologies, the collaboration of multiple microorganisms, and the combination of microorganisms and multiple repair pathways are bound to show new development trends in the near future[20]. In addition, among the existing technologies for soil remediation, ex-situ remediation technology is large, costly, and cumbersome. The development of multiple in-situ soil remediation technologies, combined with equipment to

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quickly remediate contaminated sites, and the construction of soil remediation systems will also be the focus of the future pollution remediation process.

References

[1] Li, Z., Yong-liang, C. & Ting-zhen, Y. Ecological distribution and seasonal change of soil microorganisms in pure and mixed plantations. Journal of Forestry Research 11, 106–108 (2000).

[2] Kayukova, G.P., Gareishina, A.Z., Egorova, K.V. et al. Petroleum crudes and products-Soil pollutants. Attempted classification based on biodegradation. Chem Technol Fuels Oils 35, 315–324(1999).

[3] Amlashi, N.E., Hadjmohammadi, M.R. Utilization of water-contained surfactant-based ultrasound-assisted microextraction followed by liquid chromatography for determination of polycyclic aromatic hydrocarbons and benzene in commercial oil sample. J IRAN CHEM SOC 13, 1197–1204 (2016).

[4] Gordadze, G.N., Poshibaeva, A.R., Giruts, M.V. et al. Formation of Petroleum Hydrocarbons from Prokaryote Biomass: 2. Formation of Petroleum Hydrocarbon Biomarkers from Biomass of Geobacillus jurassicus Bacteria Isolated from Crude Oil. Pet. Chem. 58, 1005–1012 (2018).

[5] Nour El-Din, N., Abdel-Moati, M. Accumulation of Trace Metals, Petroleum Hydrocarbons, and Polycyclic Aromatic Hydrocarbons in Marine Copepods from the Arabian Gulf. Bull. Environ. Contam. Toxicol. 66, 110–117 (2001).

[6] Pintado, V., Gómez-Mampaso, E., Fortún, J. et al. Infection with Nocardia Species: Clinical Spectrum of Disease and Species Distribution in Madrid, Spain, 1978–2001. Infection 30, 338–340 (2002).

[7] Chen, Xf., Huang, C., Xiong, L. et al. Microbial oil production from corncob acid hydrolysate by Trichosporon cutaneum . Biotechnol Lett 34, 1025–1028 (2012).

[8] Vahabisani, A., An, C. Use of biomass-derived adsorbents for the removal of petroleum pollutants from water: a mini-review. Environ Syst Res 10, 25 (2021).

[9] Ahn, ., Lee, ., Hong, . et al. Identification of the Phthalate-Degrading Bacteria Isolated from Phthalate-Contaminated Soil and Characterization of Their Phthalate Substrate Specificity. Bull Environ Contam Toxicol 72, 911–915 (2004).

[10] Zhao, X., Sun, Y., Huang, J. et al. Effects of soil heavy metal pollution on microbial activities and community diversity in different land use types in mining areas. Environ Sci Pollut Res 27, 20215–20226 (2020).

[11] Kim, S.U., Owens, V.N., Kim, Y.G. et al. Effect of Phosphate Addition on Cadmium Precipitation and Adsorption in Contaminated Arable Soil with a Low Concentration of Cadmium. Bull Environ Contam Toxicol 95, 675–679 (2015).

[12] García, E.M., Bastidas, C., Cruz-Motta, J.J. et al. Metals in Waters and Sediments of the Morrocoy National Park, Venezuela: Increased Contamination Levels of Cadmium over Time. Water Air Soil Pollut 214, 609–621 (2011).

[13] Ji, Ly., Zhang, Ww., Yu, D. et al. Effect of heavy metal-solubilizing microorganisms on zinc and cadmium extractions from heavy metal contaminated soil with Tricholoma lobynsis . World J Microbiol Biotechnol 28, 293–301 (2012).

[14] Yang, W., Zhang, T., Li, S. et al. Metal removal from and microbial property improvement of a multiple heavy metals contaminated soil by phytoextraction with a cadmium hyperaccumulator Sedum alfredii H.. J Soils Sediments 14, 1385–1396 (2014).

[15] Dai, S., Li, Y., Zhou, T. et al. Reclamation of heavy metals from contaminated soil using organic acid liquid generated from food waste: removal of Cd, Cu, and Zn, and soil fertility improvement. Environ Sci Pollut Res 24, 15260–15269 (2017).

[16] Dummi Mahadevan, G., Zhao, F. A concise review on microbial remediation cells (MRCs) in soil and groundwater radionuclides remediation. J Radioanal Nucl Chem 314, 1477–1485 (2017).

[17] Morales Pontet, N.G., Fernández, C., Perillo, V.L. et al. Preliminary assessment of microbial mats in seawater metal remediation. Environ Monit Assess 195, 516 (2023).

ISSN: 2710-0723

[18] Daniel, D., Jegathambal, P. & Bevers, B. In Situ Bioremediation of Textile Dye Effluent-Contaminated Soils Using Mixed Microbial Culture. Int J Civ Eng 17, 1527–1536 (2019).

[19] Popov, N., Rončević, S., Duduković, N. et al. Ex situ remediation of sediment from Serbia using a combination of electrokinetic and stabilization/solidification with accelerated carbonation treatments. Environ Sci Pollut Res 28, 14969–14982 (2021).

[20] Torracchi C., J., Morel, M.A., Tapia-Vázquez, I. et al. Fighting plant pathogens with cold-active microorganisms: biopesticide development and agriculture intensification in cold climates. Appl Microbiol Biotechnol 104, 8243–8256 (2020).