Application of Microbiotechnology in Ecological Restoration of Mines

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ABSTRACT: Recently, the research of microbiology and geology has achieved extensive development, and the application of microbiotechnology in mining-related fields has become more common. Based on this, the paper takes microbiotechnology as the main research topic with focus on its specific application in ecological restoration of mines, hoping to help.

1. Introduction
Currently, microbiological research applied in mining is mainly on bioleaching and biometallurgy, which has achieved quite a lot. In special mining areas, due to its special biochemical characteristics, there are a large number of specific microbial communities. In heavy metal polluted mining areas, fungi and bacillus are the most common. Microbes can tolerate specific heavy metal ions to a high degree and can change their biochemical or physical properties to reduce toxicity, enabling them to exist in heavy metal polluted mining areas. Due to this characteristic, mining microorganisms have gradually become the focus of modern mining research. The microbiological methods related to environmental remediation in mining areas have also attracted much attention in the treatment of environmental pollution. It can be seen that it is very necessary to study and analyze the application of microbial technology in ecological restoration of mines.

2. Research on Microbial Mineralization
The role of microorganisms in sedimentary changes, diagenesis, and mineralization is very crucial. It is not limited to combustible deposits, direct connections between the formation of some fine-grained uranium deposits and red-bed copper deposits with internal or surface microorganisms also exist. In the context of in-depth research on biomineralization, more organisms playing a role in the mineralization process has been discovered, especially the indigenous microorganisms in mineral deposits, whose mineralization effects cannot be undermined. According to existing research results, it is understood that bacteria and prokaryotic algae are both mineralizing microbial groups, and their forms of participation in the mineralization process are also different.

In the process of mineralization, the pathway of biogenesis is reflected in two aspects: 1) Biologically induced mineralization, through the application of metabolites secreted by microorganisms, the effective deposition of mineral particles can be achieved; 2) Bio-controlled mineralization, the role of microorganisms is also crucial to mineral nucleation and growth.

During the formation of different forms of deposits, microorganisms directly or indirectly participate in the mineralization process, and the diversity of minerals is obvious. Although there are certain differences in the principles and functions of microorganisms participating in the
mineralization process of different minerals, many biomineralized particles are not large, all in the range of nanometer to micrometer, and the small mineralized particles can become ore after physical diagenesis. Based on the analysis of the current situation, the abandoned mines and the surrounding environment are mainly polluted by heavy metals. It is precisely due to the excessive heavy metal ions that it is difficult to restore vegetation in the mining area. In the process of heavy metal mineralization, the resistance of microorganisms is outstanding and they can grow normally in these areas. Therefore, combining the conditions of minerals and metal ions in different mining areas, it is also of practical significance to apply mineralizing microorganisms to restore the ecological environment in the corresponding areas.

3. Specific Application of Microbial Technology in Ecological Restoration of Mines

In recent years, the development of the mining industry has accelerated significantly, and pollution problems such as soil and water sources in abandoned mines have become more serious, especially heavy metal pollution, which severely threatens human health. In the pollution treatment of abandoned mines, traditional treatment technologies are costly, inconvenient and difficult to operate, and they can easily cause secondary pollution. The emerging waste ore and wastewater treatment technology has gradually become the focus of environmental science and related mining research. Currently, Chinese researchers have proposed the idea of applying microbiological methods in the treatment of heavy metal pollution. Through the use of microorganisms to fix heavy metal particles or through metabolic pathways, toxic heavy metal ions can be transformed into non-toxic or low-toxicity states.

(1) Ecological Restoration of Polluted Mines

For a long time, the cost of controlling heavy metal pollution in soil is relatively high and difficult, and it is difficult to apply it to the restoration of large-scale mine wastelands. Currently, bioremediation generally includes microbial restoration methods, preparative restoration methods, and vegetation-soil microbial restoration methods. In the mine wasteland environment, the soil contains a lot of heavy metals, and the pH value fluctuates significantly, the ability to retain fertilizer and water is relatively weak and easily eroded. In the process of restoring the ecological environment of abandoned mines, the problem of phytoremediation is very obvious. The metabolic activity of microorganisms in the natural environment will improve the pollution of heavy metals in the soil, so the value of microbial remediation technology has gradually become prominent.

The restoration process of the ecological environment of mines by microorganisms can be divided into two stages: 1) biological fixation of heavy metals; 2) biological transformation of heavy metals. The microbial cell membrane contains many anionic functional groups, which can adsorb heavy metal cations in the form of intracellular accumulation, cell complexation and extracellular precipitation. There are many bacteria that can effectively reduce iron ions and mercury ions, and there are also some bacteria that can oxidize iron ions. After the metal valence state changes, its stability will also change. In the process of heavy metal methylation and demethylation, the volatility of this metal is also more prominent, and its own toxicity will be reduced.

(2) Ecological Restoration of Acidic Mining Wastewater

In the ecological environment of mines, mining wastewater is also a very common source of pollution, and the most harmful is the acidic mining wastewater, which has developed into a worldwide governance problem. Acidic mining wastewater is formed in the process of mining and transporting sulfide minerals. After oxidation and decomposition treatment, mining waste can be hydrated to produce sulfuric acid and form acidic water. If it was not treated in time and was instead discharged randomly, it will inevitably cause serious acid and heavy metal pollution, which will cause corrosion to various mining equipment such as pipelines, steel rails, water pumps, and concrete structures, and it is also detrimental to human health. In the study, it was pointed out that the role of bacteria in acid wastewater is prominent, so in the process of treating acidic mining wastewater, the importance of microorganisms has become more and more significant.

It has been learned from research that sulfate-reducing bacteria have a significant effect on the treatment of acidic wastewater, which can effectively reduce sulfate to a low-valence state, and
ultimately reduce it to form elemental sulfur. There is a significant difference in the oxidation rate of pyrite under bacteria and aseptic conditions. Among them, in the process of oxidizing ferrous ions by *Thiobacillus ferrooxidans*, carbon dioxide will be used and then transformed into bacterial cells, effectively reducing the acidity of mineral water and alleviating the degree of pollution\[^{4}\]. For *Thiobacillus denitrificans*, redox reactions can be carried out by using the sulfide as an electron donor, and by using $\text{NO}_3^-$ as an electron acceptor, thereby removing nitrate and sulfide in the wastewater, and elemental sulfur can be recovered.

In practice, microbial technology is applied to the ecological restoration of contaminated mine areas. The solid soil and acidic mineral water restoration are very similar, and both can be further categorized into chemical and physical methods. Among them, the physical method is to use microorganisms to fully utilize the viscosity of the microbial extracellular polymer, which can physically adsorb or precipitate the polluting heavy metal particles, thereby reducing the rate of pollution diffusion. The chemical method refers to the transformation of heavy metal ions states by microbial-synthesized enzymes through various pathways such as metabolisms to achieve the goal of reducing toxicity. The most important thing is that microorganisms can effectively remediate heavy metal pollution, so they must be resistant to heavy metal. Under normal circumstances, heavy metal resistance genes exist in microbial plasmids, so super-bacteria can be obtained by plasmid recombination, which is ecological and safe, and has a significant effect on heavy metal pollution remediation.

In conclusion, in the context of the significant acceleration of national economic development, the problem of imbalanced supply and demand of mineral resources has gradually become prominent. In particular, the "poor, fine, and miscellaneous" characteristics of mineral resources and the increased environmental pollution have directly increased the difficulty in traditional geological management of the ecological environment. The theory of microbial mineralization is an interdisciplinary subject of microbiology and geology, which effectively compensates for the shortcomings of traditional mine ecological restoration. Although the microbial remediation methodd pollute the environment to a small degree and the cost is not high, the scope of application of microbial technology to restore the ecology of mines is still not wide, mainly on the treatment of acidic mineral water and the ecological restoration of waste gas polluted mines. For this reason, the research on microbial technology should be increased and applied in the ecological restoration process of mines to effectively improve the ecological environment of mines and accelerate the sustainable development of modern mining.

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