Effect of coal mining on soil environmental quality

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Abstract: With the increasing demand for energy, coal mining, as an important means of energy acquisition, has been widely used in the world. However, the process of coal mining is often accompanied by a profound impact on the soil environment, which has aroused widespread concern in the past decades. The influence of coal mining on soil environmental quality is not only related to geological conditions and mining methods, but also related to the stability of ecosystem and the sustainability of soil function.

1. Introduction

Soil environmental quality refers to the comprehensive state of various physical, chemical and biological characteristics of soil, which determine the ability of soil to support the environment and ecosystem, it involves many aspects such as soil fertility, structure stability, pollutant content, biological diversity and microbial activity. Good soil quality is a key factor in maintaining balance of nature, plant growth and surface water quality. Therefore, it is essential to pay attention to the impact of large-scale industrial activities such as coal mining on the soil environment, which is not only related to the health and sustainable development of ecosystems, it is also an expression of responsibility to future generations. Understanding and assessing the specific impacts of these mining activities on the soil environment is the basis for formulating effective environmental protection policies and implementing soil remediation measures.

2. Direct effect of coal mining on soil environmental quality

2.1 Changes in soil structure

Coal mining activities directly affect the soil structure, the impact is multi-faceted. The mechanical operation and surface excavation in the mining process will destroy the original soil layer structure, resulting in increased soil compactness and decreased porosity. This physical change not only weakens the aeration and permeability of soil, but also affects the flow and exchange of water and nutrients in soil. Coal mining results in the removal or destruction of a large amount of topsoil, which is usually rich in organic matter and microorganisms, and is the key to soil fertility and ecological function. The loss of topsoil exposes the underlying soil to the environment, which not only reduces soil fertility, but also makes it more susceptible to erosion and pollutants. In addition, waste and loose materials from coal mining often cover the surrounding land, changing the physical and chemical property of the original soil and further affecting soil environmental quality. From the perspective of environmental ecology, the change of soil structure will also have a chain reaction to the surrounding ecosystem. As the foundation of ecosystem, the change of soil structure directly affects the growth conditions of plants. For example, compactness of the soil structure limits root growth and development and reduces the plant's ability to absorb water and nutrients. This not only affects the growth of vegetation, but may also change the composition and diversity of plant communities[1]. In addition, changes in soil structure also affect the activities of soil microorganisms, which play a key role in soil nutrient cycling and organic matter decomposition. The decrease of microbial activity will slow down the decomposition of soil organic matter and release of nutrients, and then affect the function of the whole ecosystem.

2.2 An increase in soil contamination

The increase in soil contamination due to coal mining activities is an environmental concern, especially as the increase in organic pollutants poses a serious threat to the soil environment. During mining, coal mines and their associated facilities release a variety of organic compounds, such as residues from coal and petroleum products, which often contain large amounts of harmful chemicals. These organic pollutants enter the soil by weathering and rainwater erosion, and disturb the chemical composition and biological activity of the soil. For example, pollutants such as heavy metals and Polycyclic aromatic hydrocarbon from coal mining not only threaten the survival of soil microbes, but can also have indirect effects on human health through the accumulation of food chains. In addition, the presence of organic pollutants can alter soil pH and electrical conductivity, affecting the availability of nutrients in the soil and the growth of plants.

The accumulation of organic pollutants in soil may also cause a series of environmental problems. These pollutants are often difficult to degrade under natural conditions and thus persist in the soil. This kind of long-term pollution not only affects soil fertility and productivity, but also may cause the imbalance of soil ecosystem. For example, certain organic pollutants may inhibit or destroy the activity of beneficial microorganisms in the soil, thereby affecting the soil's self-purification capacity and nutrient cycling processes. Organic pollutants in the soil may also migrate through groundwater to wider areas, resulting in greater environmental contamination[2]. In addition, the accumulation of these pollutants in the soil may also have toxic effects on soil animals, plants and the entire ecosystem. For example, some organic pollutants inhibit the growth of plant roots, thereby affecting the normal growth and development of plants.

2.3 A decline in the fertility of the soil

Coal mining has had a significant impact on the decline in soil fertility due to the direct destruction of the natural structure and balance of nature of the soil by mining activities. In the process of coal mining, a large amount of soil is excavated, moved or covered, resulting in the loss of original soil layers, especially the topsoil rich in organic matter and microorganisms. This kind of physical destruction makes the content of organic matter in the soil decrease, and then affects the soil microbial activity. As microbes play a key role in organic matter decomposition, nutrient cycling and soil structure maintenance, their reduced activity directly affects soil fertility. In addition, the mineral components of the soil, such as nitrogen, phosphorus, potassium and other nutrients, are also affected by mining activities. Soil erosion and erosion caused by coal mining causes these key nutrients to be stripped or lost, reducing soil fertility and productivity.

Coal mining also causes chemical property changes in the soil environment, further reducing soil fertility. Pollutants such as organic pollutants and heavy metals from mining activities accumulate in the soil, changing the pH and electrical conductivity of the soil, which are not conducive to plant growth and microbial activity. Especially, the accumulation of heavy metals will poison the soil microbial communities and plant roots and affect their normal functions. In addition, these pollutants can affect the availability of nutrients in the soil, making it more difficult for plants to absorb and use nutrients in the soil. Long-term soil pollution not only reduces the immediate fertility of the soil, but also may lead to a long-term decline in soil productivity. Therefore, the impact of coal mining on soil fertility is a far-reaching and complex issue, not only affecting the current soil environment, but also may pose a long-term threat to future soil health and ecosystem stability.

3. Indirect effects of coal mining on soil environment

3.1 Effect of coal mining on soil water cycle

The influence of coal mining on soil water cycle is mainly manifested in the change of groundwater level. Mining activities require the removal of groundwater in order to keep the mine dry and safe, which leads to the lowering of the groundwater level in the surrounding area. The decrease of groundwater level has a significant effect on soil water balance, especially in arid and semi-arid areas. Falling groundwater levels not only affect the natural replenishment of water in the soil, but may also lead to lower water levels in surface water bodies such as rivers and lakes, affecting the water cycle and availability of water resources throughout the region. In addition, changes in the water table can affect the uptake and use of water by plants, especially in plant ecosystems that depend on groundwater. These changes may lead to a reduction in vegetation cover, which in turn affects surface water evaporation and soil water cycling.

The change of soil moisture and permeability is also one of the indirect effects of coal mining. The excavation of the surface and the use of heavy machinery during mining destroy the natural structure of the soil and make it more compact. The increase of soil compactness will reduce soil porosity and soil permeability[3]. This change not only affected the soil water retention capacity, but also affected the vertical and horizontal movement of water in the soil. When soil permeability decreases, rainwater can not penetrate into the deep soil, and more water will be lost in the form of surface runoff, resulting in further loss of soil water. In addition, changes in soil moisture and permeability also affect soil microbial activity and plant root development, thereby affecting soil biological activity and ecosystem health.

3.2 Soil acidification caused by coal mining

The problem of soil acidification caused by coal mining is mainly due to the release of sulphides and nitrides during coal combustion, which react with water vapor in the atmosphere to form acid rain. When acid rain falls to the ground, it will lead to soil acidification, during which the pH value of the soil will decrease significantly. Soil acidification not only changes the chemical composition of soil, but also destroys the physical structure of soil. For example, acidification can lead to the dissolution and loss of beneficial minerals such as calcium and magnesium in the soil, while increasing the solubility of harmful metals such as aluminum in the soil. These chemical reaction adversely affect the nutrient balance and microbial activity of the soil, reducing its natural fertility and productivity. In addition, acidified soils also affect the quality of groundwater, increasing the acidity of surface water and thus affecting the entire aquatic ecosystem.

The effect of soil acidification on vegetation growth is especially obvious. In acidified soil, the availability of essential nutrients decreases and the concentration of harmful metal elements increases, which directly affects the growth and development of plants. In acidic soils, plants often have stunted root development and reduced ability to absorb water and nutrients, leading to slow growth and even death. Especially for some acid-sensitive plant species, soil acidification can lead to their reduction or disappearance in affected areas, thus affecting the species diversity and stability of the entire ecosystem. Long-term soil acidification can also change the structure and function of vegetation communities, and affect ecosystem services such as carbon fixation and nitrogen cycling.

3.3 Effects of coal mining on soil microbial diversity

Coal mining has a significant impact on soil microbial diversity, which is mainly reflected in the change of microbial community structure. The physical disturbance and chemical pollution caused by mining, especially the accumulation of heavy metals and organic pollutants, have a strong impact on soil microbial community. These pollutants can directly inhibit or kill certain microbial populations, resulting in a reduction in microbial diversity. The decrease or disappearance of microbial population destroyed the interaction and balance between microorganisms in soil ecosystem, and affected the structure and function of soil microbial community. For example, some key nitrogen-fixing bacteria, decomposing bacteria and other beneficial microorganisms may not survive in contaminated soil, thus affecting nutrient cycling and organic matter decomposition in the soil. In addition, the accumulation of heavy metals and other pollutants in soil may lead to the resistance of microorganisms to these toxic substances, thus changing the composition and function of soil microbial community[4].

The damage of coal mining to soil micro-ecological environment is also very serious. Soil micro-ecological environment is the basis of microbial survival and activity, including soil physical structure, chemical composition and biological activity. The soil structure destruction and chemical pollution caused by mining activities changed the pH value, organic matter content and nutrient status of soil, which directly affected the living environment of microorganisms. When the soil environment becomes more extreme and unstable, many microorganisms will not be able to adapt to the new environmental conditions. For example, soil acidification and heavy metal contamination can lead to a decrease in the number of beneficial microorganisms in the soil, while the number of microbes that are more tolerant of these pollutants may increase. This change not only reduced soil microbial diversity, but also affected the contribution of soil microbes to soil health and ecological function. For example, the role of microorganisms in organic matter decomposition, nutrient transformation and pathogen suppression may be limited.

3.4 Effect of coal mining on heavy metal accumulation in soil

An important effect of coal mining on soil environment is to promote the migration and transformation of heavy metals in soil. During the process of coal mining, there are a lot of surface excavation and material transportation, which lead, cadmium, Mercury and other heavy metals are brought to the surface or into the soil environment. The behavior of these heavy metals in soil is very complex, including adsorption, ion exchange, precipitation and redox reactions. These processes not only change the form and bioavailability of heavy metals in soil, but also increase their mobility in the environment and ecological risks. For example, some heavy metals may exist in forms that are more readily absorbed by plants and thus enter organisms through the food chain. In addition, the migration and transformation of heavy metals are also affected by soil pH, organic matter content and soil moisture, which means that soil environmental changes caused by coal mining will further affect the behavior of heavy metals.

The accumulation of heavy metals in soil is a serious threat to soil ecological security. Heavy metals are persistent and bioaccumulative. Once they enter soil, they are difficult to be removed or degraded. The accumulation of these elements is not only toxic to microorganisms and plants in soil ecosystems, but may also pose long-term health risks to soil animals and higher organisms. In soils with high concentrations of heavy metals, the growth and development of plants are inhibited, and heavy metals absorbed by their roots may be passed on to consumers, including humans, through the food chain. This not only affects soil biodiversity and ecological function, but may also pose a threat to public health. In addition, the accumulation of heavy metals affects the physical and chemical property properties of the soil, such as soil structure and pH, which in turn affects soil fertility and productivity.

4. Soil remediation and control in coal mining area

4.1 Soil remediation technology

Soil remediation technology in coal mining area is the key to solve the problem of soil pollution. These technologies aim to restore the natural structure, fertility and biological activity of the soil and to mitigate or eliminate the negative impacts of mining activities on the soil environment. Soil remediation technology includes physical, chemical and biological methods, each has its own characteristics and application conditions. Physical methods mainly include soil replacement and isolation, that is, the removal or isolation of contaminated soil to reduce the impact of pollutants on the environment. Chemical methods include the use of various chemicals to neutralize or change the chemical form of pollutants in the soil to make them more stable or less harmful to the environment. Bioremediation technology, especially phytoremediation (plant nutrition) and microbial remediation, utilizes the natural functions of plants and microorganisms to degrade, absorb or immobilize pollutants in soil. These technologies are generally more environmentally friendly because they use natural processes to purify the soil, but their remediation effectiveness may be affected by soil type, pollutant types and environmental conditions.

When choosing appropriate soil remediation technologies, consideration should be given to soil properties, pollutant types and concentrations, remediation objectives, and economic and social factors. For example, chemical remediation or phytoremediation may be required for heavy metal-contaminated soils, while microbial remediation may be more appropriate for organic pollutants. In addition, a combination of different remediation technologies, such as physical isolation and bioremediation, can more effectively address complex soil pollution problems. Effective soil remediation requires not only scientific and rational technical programmes, but also long-term monitoring and management to ensure the sustainability and stability of remediation effects[5].

4.2 Ecological restoration and Environmental monitoring

Ecological Restoration plays a key role in soil remediation in coal mining area. This process involves not only the restoration of the physical, chemical and biological properties of the soil, but also the reconstruction of the structure and function of damaged ecosystems. The main objectives of ecological restoration are to promote the restoration of biodiversity, to rebuild plant communities, to restore the natural fertility of soils, and to rebuild ecosystem services such as soil and water conservation and carbon cycling. This can be achieved by growing native plants to restore vegetation cover, reconstructing soil hierarchies and restoring soil microbial communities. Through these measures, we can gradually restore the natural state of soil and ecosystem health. In this process, the selection of suitable plant species and restoration strategies is essential, which requires an in-depth understanding of local ecological conditions and soil properties..

Environmental monitoring is another key part of the recovery process. Regular monitoring of soil physical and chemical property, biodiversity, vegetation cover and other relevant ecological indicators can assess the progress and effectiveness of restoration efforts. The Environmental monitoring not only helps to understand the immediate impact of recovery measures, but also provides long-term data support to guide future adjustments and improvements in recovery strategies. In addition, Environmental monitoring can help to identify new environmental problems or potential ecological risks in a timely manner and take appropriate preventive and response measures. Effective Environmental monitoring requires a combination of monitoring techniques and methods, including remote sensing monitoring, soil and water quality analysis, and biodiversity surveys. Through continuous and systematic Environmental monitoring, it can provide scientific basis for ecological restoration in coal mining areas and promote healthy and sustainable development of soil and ecological environment.

5. Conclusion

With the development of science and Technology and the enhancement of environmental awareness, more efficient and environmentally friendly soil remediation technology and ecological restoration methods are expected to be developed and applied. This will not only solve the problem of soil pollution more effectively, but also promote the rapid recovery of the ecosystem and sustainable development. At the same time, advances in Environmental monitoring technology will provide more accurate and comprehensive data support for soil remediation and ecological restoration, making restoration more scientific and systematic.

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