



# Research on Ecological Environment Issues and Ecological Restoration in Mining Areas

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## ABSTRACT

A comprehensive exploration was conducted on the ecological challenges faced by the three major environmental elements of the mining area ecosystem-soil, water, and atmosphere, and ecological restoration strategies were systematically elaborated to address these issues. In the field of land, reclamation and vegetation reconstruction technologies have been implemented; Ecological restoration and resource utilization measures have been taken for the water area. During the mining process in the mining area, subsidence prevention and control technologies including full filling mining, strip mining, and filling of overlying rock separation zones were adopted. At the same time, for the prevention and treatment of ground subsidence and cracks, a variety of technical means such as monitoring and early warning, temporary engineering reinforcement, anti-seepage treatment, vegetation reconstruction, and drainage ditch excavation have been comprehensively applied.

## KEYWORDS

Coal mining; Ecological environment; Ecological restoration; Mining subsidence.

## 1. INTRODUCTION

As the leading force in China's energy structure, the development of coal resources has not only promoted industrialization, but also caused significant ecological costs. In the past 30 years, large-scale mining activities have caused significant damage to the ecological environment, endangering national security and ecosystem stability, as well as negatively affecting the quality of life of mining residents and the long-term development of regional economy. In this context, adopting scientific and systematic methods for ecological restoration of coal mine subsidence areas has become a key issue that urgently needs to be overcome in the development process of mining areas.

## 2. OVERVIEW OF ECOLOGICAL ENVIRONMENT AND GOVERNANCE RESEARCH IN COAL MINING AREAS IN CHINA

Land reclamation, as the core means of rectifying damaged land, has undergone long-term development in China. In the late 1950s and early 1960s, China launched a large-scale land consolidation project. In the 1990s, this field gradually gained widespread attention from the government and the public. In 2011, the Regulations on Land Reclamation were reviewed and approved by the State Council Executive Meeting and officially implemented; In 2019, the Ministry of Natural Resources further issued a new version of the Implementation Measures for the Regulations on Land Reclamation, providing important institutional guarantees for implementing the national policy of land resource protection and regulating reclamation practices. With the environmental challenges and natural disasters caused by mineral resource development, as well as the increasing demand for reclamation theory and technology, land reclamation in mining areas has



gradually developed into an emerging interdisciplinary field that combines scientific and practical aspects.

The development of mineral resources has a significant impact on land structure and ecological environment, disrupting the balance of natural ecosystems and posing a potential threat to the lives and health of residents in mining areas. Among them, the wastewater generated in the process of coal mining contains a variety of harmful substances, and the unqualified discharge has become the most prominent environmental problem at present. Although it is widely recognized in academia and society that mining activities can cause environmental problems such as water pollution and surface subsidence[1], there is still uncertainty regarding the severity, spatial scope, and duration of these impacts, and research and exploration are still ongoing.

China's research in the field of ecological restoration of abandoned mining areas is relatively lagging behind, but significant progress has been made. Since the 1960s, China has been implementing mine remediation projects, initially focusing on basic measures such as leveling waste rock sites and covering tailings ponds with soil for greening[2]. The current research focus has expanded to areas such as mining area environmental assessment, ecological restoration strategies, and circular economy models. With increasing policy support, ecological restoration and resource reuse in mining areas are receiving increasing attention, and related technological research has gradually become a hot topic. Taking Han Baoping's research on the Datong mining area as an example, he deeply explored the impact mechanism of mining activities on surface runoff, geological disasters, and groundwater systems, revealed the interaction law between surface water and groundwater during coal mining, and the migration and diffusion characteristics of pollutants in the hydrological system. These findings provide important basis for environmental impact assessment in different regions.

### **3. THE IMPACT OF COAL MINING ON THE ECOLOGICAL ENVIRONMENT**

The development of mineral resources will bring many environmental challenges, which will intensify the contradictions between population, resources, and environment. It is worth noting that different mining methods have significant differences in their impact on the environment.

#### **3.1. Impact of Coal Mining on Land Environment**

The most direct impact of mineral resource development on surface morphology is manifested as ground subsidence. Among them, the settlement phenomenon caused by underground mining methods is the main cause of farmland damage and reduction. This kind of settlement not only causes surface cracks, hinders the normal growth of crops and vegetation, but also exacerbates soil erosion. In addition, the subsidence process can also cause a reduction in arable land area, which has a negative impact on agricultural production, farmers' income, and quality of life. From a landscape perspective, subsidence can alter the original terrain features, destroy the natural landscape, and thus affect the overall integrity and stability of the regional ecological environment, which may lead to the degradation of the ecosystem.

#### **3.2. Impact of Coal Mining on Water Environment**

The development of mineral resources and the utilization of groundwater are often carried out simultaneously, and coal mining activities have a significant impact on the hydrological system. Firstly, the mining process can alter the geological structure and disrupt groundwater circulation. Due to the presence of aquifers between coal seams, as the mining depth increases, it is necessary to drain the interlayer groundwater, resulting in the loss of shallow water resources. At the same time, the pollution of mine wastewater has deteriorated the quality of high-quality groundwater, not only affecting the supply of water resources, but also reducing their value for use. Pollutants further affect

groundwater through soil infiltration, posing a threat to drinking water safety. The surface fissures caused by mining provide channels for surface water to infiltrate into the mining area, resulting in a reduction in surface runoff and a widespread decline in groundwater levels, affecting regional water supply. In addition, the wastewater discharged from various facilities in the mining area contains radioactive substances, acidic components, and suspended solids, polluting the surrounding soil, endangering crop and vegetation growth, and causing damage to agricultural, forestry, and other resources. The upper collapse caused by coal mining exacerbates water scarcity, especially in water scarce areas, which further exacerbates the supply-demand imbalance. At the same time, it also increases the difficulty of treating pollutants such as mine water and coal gangue, affecting regional environmental quality and hindering the coordinated development of society, economy, and ecology[3][4].

### **3.3. Impact of Coal Mining on Atmospheric Environment**

The diffusion of atmospheric pollutants in mining areas is mainly constrained by factors such as wind speed, airflow, temperature difference, and pollutant concentration gradient. In the process of coal mining, the release of a large amount of coal dust and smoke not only changes the atmospheric composition of the work area, but also significantly reduces visibility and increases the risk of safety accidents. More seriously, these emissions contain high concentrations of harmful components that can alter the temperature and humidity conditions of the local environment, affect air quality, and may trigger extreme weather phenomena such as acid rain and haze.

## **4. ENVIRONMENTAL PROTECTION MEASURES IN THE DEVELOPMENT AND UTILIZATION OF COAL RESOURCES**

### **4.1. Ecological Restoration Technology**

#### **4.1.1. Land Reclamation Technology**

Based on the investigation of the damaged terrain and soil characteristics in the mining area, a land restoration plan is formulated according to local conditions to minimize the impact of mining activities on the ecological environment. Land restoration technology has the characteristics of multidimensionality, systematization, diversification, and strong regional adaptability[5]. In practice, this technology is mainly divided into two categories: one is engineering restoration technology, which creates suitable conditions for vegetation growth through physical filling or material backfilling; The second is bioremediation technology, which uses biological means to fundamentally improve soil structure, increase nutrient content, and thus rebuild a healthy ecosystem[6].

#### **4.1.2. Vegetation restoration techniques**

The ecological system in mining areas is facing severe challenges, especially the widespread occurrence of heavy metal exceedance in tailings pond areas, which poses significant difficulties for vegetation reconstruction and soil remediation. Vegetation reconstruction technology aims to accelerate the process of ecological restoration, improve the efficiency of soil and water resource utilization, and scientifically plan plant communities based on principles of botany, ecology, mining terrain characteristics, and soil and water conservation needs[7]. This technology mainly covers four key aspects: screening and community configuration of suitable plants, maintenance of vegetation coverage, optimization of cultivation techniques, and management and monitoring of restoration areas. It is worth noting that China has developed an innovative patented technology for vegetation restoration, which utilizes wild sweet potatoes to achieve the dual goals of vegetation reconstruction and comprehensive soil pollution control in mining areas.

### 4.1.3. Water ecological restoration and development technology

The development of mineral resources poses a pollution risk to the groundwater system. The surface subsidence caused by mining activities can form water accumulation areas in collapsed areas, and long-term accumulation may lead to surface water infiltration and carry pollutants into groundwater layers. To address the issue of water pollution in mining areas, the following measures have been taken: firstly, a dedicated drainage system has been established to collect and store acidic wastewater, which is then concentrated through evaporation for centralized treatment; The second is to use new water pump technology to dehydrate coal slurry water in stages, achieving underground recycling of water resources or comprehensive recovery after treatment [8,9].

## 4.2. Mining subsidence prevention and control technology in mining areas

### 4.2.1. Full filling mining

After the completion of coal mining operations and before the roof collapses, using solid materials to tightly fill the goaf can effectively control the settlement of the roof rock layer, reduce surface deformation, and protect ground buildings and farmland. Among various filling methods, water sand filling has the best effect on reducing surface subsidence, followed by wind filling and gangue self retention filling. However, the backfill mining method requires the configuration of specialized equipment and facilities, as well as ensuring sufficient backfill materials, which leads to significant initial investment in the mine and correspondingly increases the production cost per ton of coal [10].

### 4.2.2. Strip mining

In the process of mineral resource development, scientific mining parameters are formulated by analyzing the combination characteristics of coal seams and overlying rocks, and supporting coal pillars are retained in the mining area. This strip mining technology requires reserving some coal resources as support structures for the overlying strata during implementation[11]. Although it may cause a certain degree of resource loss, it can effectively control the movement of the overlying strata and reduce surface deformation. However, this technology has obvious drawbacks: multiple tunnels need to be opened during the mining process, which increases the workload; Meanwhile, due to the limited production capacity of a single roadway, the overall mining efficiency is reduced, which in turn affects the economic benefits of the enterprise [12].

### 4.2.3. Filling of Overburden Separation Zone

Based on the three zone theory formed by the movement of overlying strata in goaf, high-pressure grouting is carried out through drilling during a specific period of time after mining operations to fill and reinforce the space in the separation zone. This method transforms the masonry beam structure into a stable continuous beam system, effectively preventing the sinking space of the isolation layer from transferring to the surface, thereby reducing or delaying ground settlement and protecting surface buildings and farmland. However, the implementation of this technology is difficult and still requires in-depth research and improvement [13].

## 4.3. Treatment of Ground Collapse and Cracks

For mining subsidence areas and subsidence zones that are in an unstable state, safety hazards can be eliminated by implementing engineering measures such as monitoring and warning, temporary support, etc; For subsidence areas that have stabilized, comprehensive treatment methods such as convex cutting and filling, leveling and backfilling, anti-seepage treatment, vegetation restoration, and drainage ditch excavation can be adopted [14]. Specifically, for surface cracks with smaller scale and less severe damage, soil and stone filling and compaction combined with anti-seepage treatment can be adopted; If the crack size is large and the damage is severe, more effective repair measures such as grouting filling should be adopted.

## 5. OUTLOOK

In the context of the new era of socialism with Chinese characteristics, the coal industry is facing increasingly strict constraints on ecological environment protection. The lagging ecological restoration in mining areas not only affects economic development, but also limits human living space. The decline of the self purification ability of the ecological environment and the reduction of environmental capacity will constrain the coordinated development of society and economy. Therefore, exploring scientifically reasonable mechanisms and technologies for ecological restoration in mining areas has profound significance for China's environmental protection, ecological civilization construction, and legal system improvement, and will continue to deepen with the deepening of mining activities.

Currently, there are still many urgent problems to be solved in coal mining in China. The ecological and environmental problems caused by mining activities not only affect the lives of residents in mining areas, but also constrain the development of the national economy. Repairing damaged mining ecosystems is a complex system engineering that involves multiple aspects such as topography, hydrology, soil and vegetation. Due to human interference, the ecological restoration process in the mining area is slow, and it takes time to develop a restoration plan. During this period, it is necessary to fully utilize the land resources in mining areas, draw on advanced domestic and foreign experience, change our mindset, and achieve resource recycling, such as transforming subsidence areas into artificial lakes, to fundamentally solve environmental pollution problems. At the same time, in order to achieve sustainable development in mining areas, it is necessary to strengthen ecological environment protection in all aspects.

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