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Study on ecological restoration and management of historical abandoned mines in Enhe town area of Zhongning County

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Abstract: *To further explore the ecological environment problems and restoration countermeasures of abandoned mines, the ecological restoration project of abandoned mines in Enhe town area of Zhongning County was studied. Based on the field measurement and identification of many land resource loss data, the occurrence law of ecological restoration of abandoned mines left over by history is analyzed. The results show that the abandoned mines in Enhe town of Zhongning County have the conditions of destroying topography, land resources, biodiversity, and geological environment. According to the principle of adjusting measures to local conditions, the corresponding recovery and processing methods are adopted for different map points, such as landscape restoration, land resources recovery and restoration, mine vegetation restoration, mine geological environment hidden danger management, monitoring, and post-management and protection. The practice results show that the above measures have achieved good economic and ecological benefits.*

Keywords: *Abandoned Mines; Ecological Restoration; Geological Environment; Zhongning County*

1. Introduction

The Yellow River basin is an important economic development zone in China. Its ecological environment quality is not only the basis and premise of its sustainable development [1], it is also related to the realization of the major national strategies for ecological protection and high-quality development in the Yellow River basin [2]. The protection of the Yellow River is of vital importance to the great rejuvenation of the Chinese Dream. Although the development and utilization of mineral resources in the Yellow River basin has played an important role in promoting economic growth and technological progress, it is also accompanied by complex geological environment challenges caused by mining, such as inducing geological safety hazards, changes in the original terrain features, damage to the natural landscape, aggravated soil erosion, etc., these adverse effects restrict the sustainable development of local economy [3]. With the continuous advancement of economic development, mining development has become an important pillar industry in the development of the national economy [4], taking the abandoned mine ecological restoration project in Enhe Town, Zhongning County as an example, focusing on solving the environmental problems left over by mining, through precise policies, not only the ecological environment has been rapidly improved, but also a solid foundation has been laid for more long-term ecological, economic and social benefits, the harmonious coexistence of mineral development and environmental protection has been realized. It not only highlights the feasibility and necessity of ecological restoration, but also promotes the whole industry to develop in a more efficient direction [5]. According to the spirit of Green Mine Construction [6], sustainable development is the only way for mine construction [7], measures for restoring the ecological environment of mines according to local conditions [8] are an inevitable choice for achieving high-quality development of mines [9].

2. Summary of the study area

Zhongning County is located in the central part of the Ningxia Hui Autonomous Region and belongs

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to the city of Zhongwei. It is bordered to the east by the city of Qingtongxia, to the west by the city of Zhongwei, to the south by Tongxin County, and to the north by Alxa left Banner of Inner Mongolia, the geological structure is located in the eastern end of the corridor transition zone of the Qinling geosynclinal fold system in Kunlun and near the western Ordos Depression Zone of the Sino-korean paraplatform. In the geological history, the area is a relatively depressed active area, and the overall terrain is inclined from west to east and from south to north. The county is located in the transition area between the Inner Mongolia Plateau and the Loess Plateau, the county is between 1100 meters and 2955 meters above sea level, surrounded by mountains and a low-lying basin in the middle.

The study area is located in the ENHE town area of Zhongning County, including Enhe Town, Mingsha Town and Baima Township(Fig. 1). The total of 56 abandoned mines are located in the study area, with geographical coordinates ranging from 105°15′56′ to 106°04′24′ , north latitude: 36°54′17′ - 37°44′07′ . The county is about 90 km long in the north and south, 50 km wide in the east and west, with a total area of 3280.17 km^2. It is located in the eastern part of the northwest region of our country. It is the transition zone between the Inner Mongolia Plateau and the Loess Plateau, with an altitude of 1160-2025 m, climate type for the North Temperate Continental monsoon climate, winter cold long, hot summer short, late spring, early autumn cool, large temperature difference, long sunshine, and strong radiation, dry and windy. The lowest temperature in winter -30 °C, hot summer, the highest temperature 37°C, large temperature difference between day and night, generally more than 10°C. The climate is dry, less rainfall, evaporation, the average annual precipitation of about 200 mm, the average annual evaporation of more than 2000 mm. June to September is the main precipitation period, 60-70% of the annual precipitation concentrated in this period, frequent rainstorms, sometimes triggered flash floods. October to May is the monsoon season. Wind speed is generally 3-5 m/s, the maximum wind speed can reach 30 m/s, often forming sandstorm weather. The area belongs to the Yellow River basin. The Yellow River enters from Shengjinguan, the county runoff is about 68 km, 5-year flood peak flow is 4460 m^3/s, 10-year flood peak flow is 5130 m^3/s, the soil type is mainly sierozem, the desert saline soil is second, the sierozem is widely distributed in the control area, the soil texture is coarse, which is affected by the biological climate of the desert grassland. There is a certain humus and weak leaching. The vegetation belongs to the temperate desert grassland area, to perennial plant, shrub, semi-shrub-based, less population structure is simple, lack of forest resources, vegetation is covered by 25%-56%.

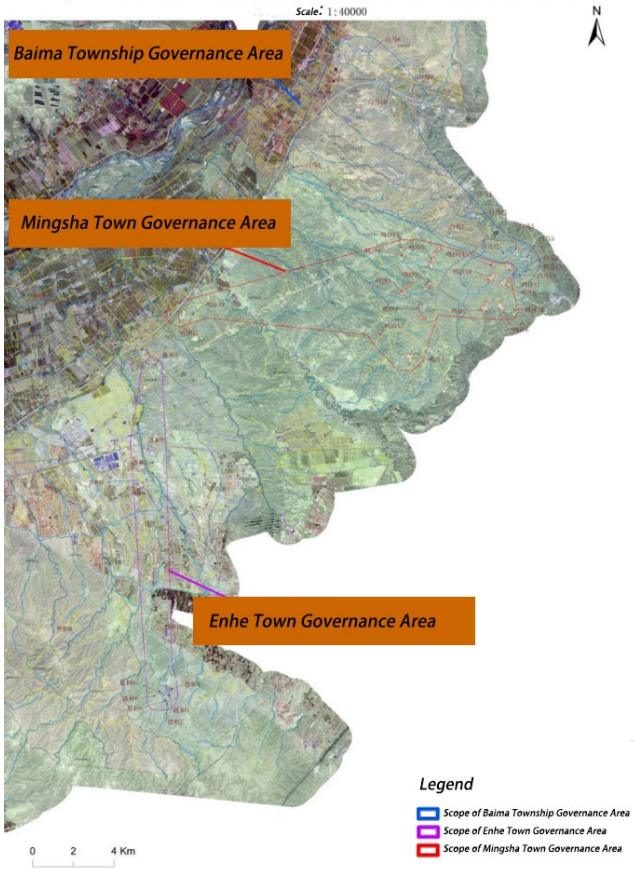

Fig. 1 Partition Map of Governance Blocks in the Research Area

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3. Ecological and environmental problems of abandoned mines

In Enhe town, Zhongning County, there are abandoned mines left over from history with ecological and environmental problems, which are mainly manifested in the destruction of topography and geomorphology, the destruction of mountains, the chaos of slag piles, and the collapse and landslide of steep slopes, soil degradation, topsoil stripping, nutrient loss and desertification affect agricultural production, as well as water pollution, the discharge of waste residue and wastewater without treatment cause harmful substances such as heavy metals to pollute rivers, lakes and groundwater.

3.1 Destruction of topography and landscape

The historical mines in Enhe town of Zhongning County have changed the original landforms and seriously damaged the local landforms, especially the open-pit mines. The study area has an area of 324.97 hm²and 41 governance points, which are divided into three governance areas: Enhe town governance area, Mingsha town governance area and Baima Township governance area, the main topographic and geomorphic damage in the control area is the excavation of open pit and the destruction of slag pile. In some open-pit mines and underground mines, the problems of water inflow are widespread, which seriously affects the consistency and environmental safety of mining resources development [10]. In mining areas with unstable geological environment conditions, vegetation coverage and rock exposure will limit the safety and stability of geological environment conditions, and special environmental problems such as the uneven displacement of mountains will indirectly aggravate the occurrence of geological disasters [11].

3.2 Loss and occupation of land resources

The main types of land destroyed by 37 control points in the five control areas were cultivated land, forest land, grassland, industrial and mining storage land, residential land, public management and public service land, transportation land, and other land.

The historical mining activities in the area occupied and used a large amount of land in the area, causing serious damage to land resources. It is mainly manifested in the fact that the surface of the Earth has been excavated in a large area, forming pits of different depths and difficult to restore, which makes the land flatness completely destroyed and can not be directly used for agricultural cultivation or construction development, the disordered accumulation of waste residue covers a large area of available land, resulting in the waste and idleness of land resources, and the infiltration of chemicals from the mining process into the soil, resulting in the imbalance of soil ph and the loss of nutrients, the fertility of the land has declined dramatically, severely reducing the productivity of the land.

3.3 Biodiversity loss

The main ecological and environmental problems under the current conditions in the control area include the formation of high and steep slopes by mining, the destruction of land resources caused by sand mining, the destruction of topography and landscape, the destruction of ecological environment, and the intensification of soil erosion, historical mining activities have had a profound impact on the natural landscape of the area, reshaping geomorphic features, impairing soil structure, reducing water retention capacity, and interfering with climatic conditions.

3.4 Mine geo-environmental hazards

There are 56 abandoned mines left over from history in Zhongning County, with a total control area of 324.97 hm²and 91 geological hazard points, including 12 points in the control area of Enhe town, with an area of 28.85hm², there are 12 potential geological hazard points, 28 points in the management area of Mingsha town with a total management area of 159.09 hm²and 55 potential geological hazard points, and 16 points in the management area of Baima Township with a total management area of 137.03 hm², 24 potential geological hazards. According to the field investigation, there are tensile cracks at the top of the slope in the control area. Under the action of rainfall and self-weight, it is easy to cause geological disasters such as collapse. However, most of these geological disasters are far away from the production and living areas of residents, and the threat of geological disasters is small. The scale of the disaster site is small, and the hidden danger of geological environment can be eliminated through simple engineering treatment.

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4. Practice of ecological restoration and treatment

There are 56 abandoned mines left over from history in the project. The main control contents include mine terrain landscape restoration, water and soil resources restoration and rehabilitation, mine vegetation restoration, mine geological environment disaster control and monitoring, post-management and protection, and so on, given the problems of vegetation damage, topography and landscape damage and soil pollution caused by abandoned open-pit mines, the comprehensive improvement of abandoned mines and land left over from history was carried out in the Liupan Mountain Ecological Extension area, according to the Order of safety, ecology and landscape, measures such as slope trimming, site leveling and sowing grass seeds were taken to restore topography and geomorphology, restore surface vegetation and prevent soil erosion.

After the implementation of the project, the restoration and Greening area reached 321.41 hm^2, of which 1002525 shrubs were planted and 309.21 hm^2 of grass seeds were scattered. The survival rate of forest and grass vegetation reached 80%, and the vegetation coverage increased to 43%, soil and water conservation service capacity increased by 10%, enhanced vegetation carbon sequestration capacity of 0.1 $t/(hm^2 \cdot a)$, the post-maintenance duration of 2 years.

4.1 Restoration of topography and landscape

The topography and geomorphology improvement project mainly aims at the high and steep slopes, mining pits and slag piles formed by mining activities in the project area, and adopts measures such as excavation, filling and site leveling. When building a retaining structure in fill area, full consideration should be given to uneven settlement, overall stability and local stability of slope [12]. For the water mining pit, targeted to take the “Deep fill shallow” measures [13].

4.2 Restoration and remediation of soil resources

The main soil type in the project area is sierozem, followed by desert saline soil. The sierozem is widely distributed in the control area, which is a quaternary alluvial deposit. The soil texture is coarse, which is affected by the biological climate of desert grassland, there are some humus and weak leaching, and the profile can be divided into organic layer, calcic horizon and parent material layer from top to bottom. Mining has caused serious damage to the original soil structure, which is often accompanied by toxic and harmful substances, the following improvements are needed:

4.2.1 Soil reconstruction works

Soil reconstitution engineering aims to improve the physical, chemical, and biological attributes of damaged soils so that they regain good structure and fertility to support plant growth and ecological balance. The specific measures of soil reconstruction are as follows:

(1) Improvement of soil physical structure: through the mechanical operation of deep tillage and plowing, harrowing and compaction, the aeration and water permeability of the soil is increased, and the root penetration ability is improved.

(2) Organic matter addition: the application of compost, green manure or other organic materials increased the content of soil organic matter and the stability of soil aggregate structure.

(3) Microbial remediation: the introduction of beneficial microorganisms, such as rhizosphere fungi and bacteria, promotes plant nutrient uptake and soil structure formation [14].

(4) pH adjustment: according to the specific situation of soil pH, the application of lime or sulfur and other materials to adjust, and optimize the plant growth environment.

4.2.2 Earthwork

To ensure the effectiveness of vegetation restoration, it is necessary to cover the ground. According to the existing soil conditions, 0.2 m thickness is designed to isolate pollutants, improve soil environment, improve soil structure, increase soil water capacity and reduce surface runoff Secondly, the vegetation root system can consolidate the soil and improve the soil's anti-erosion ability, and the design of green maintenance projects to ensure the survival rate of vegetation in the project area, increase vegetation coverage in the project area.

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4.2.3 Filling works

The selection of backfill materials should meet the engineering requirements, which usually require good compaction performance, sufficient bearing capacity and suitable particle size distribution, and the slightly acidic sandy loam is the best. The afforestation soil should not contain stone impurities with a diameter greater than 5 cm, and the gravel content should not exceed 20%. Backfill material should be layered, with each layer generally no thicker than 30 cm to facilitate compaction, and after each backfill layer is completed, a compactness test should be carried out to ensure compliance with design specifications. The soil quality meets the standard requirements of "Quality control standard for land reclamation" [15]. Secondly, in special circumstances, the backfill project may need to take additional measures, such as the use of impermeable membranes to prevent groundwater contamination, the installation of drainage systems to ensure that the backfill area is dry, and the use of anti-seepage measures, or the use of high-strength materials to withstand heavy loads. Backfilling operations should comply with safety regulations to prevent injury to workers and damage to the surrounding environment. At the same time, measures should be taken to reduce dust and noise and protect the ecological environment around the site.

5. Key issues and solutions

5.1 Soil compaction problems and solutions

The main soil type of historical heritage abandoned mines in Zhongning County is sierozem, followed by saline soil. In the control area, the distribution of Sierozem is more extensive, belonging to the quaternary alluvial deposits, soil texture is coarse, poor permeability and physical and chemical properties. This makes it difficult for seeds to penetrate the soil after germination, even in some areas with serious hardening. To solve this problem, cattle manure, sheep manure and sawdust powder were added based on chicken manure, and a variety of methods were used to cure the soil quality of the dump, to improve the soil quality and solve the problem of compaction of the surface soil [16].

5.2 Lack of water resources and countermeasures

According to the meteorological data of Zhongning County Meteorological Bureau from 2000 to 2021, the annual average precipitation is about 200 mm, the annual average evaporation is more than 2000 mm, and the groundwater recharge mainly comes from the vertical infiltration of atmospheric precipitation, the main discharge mode is underground runoff discharge, a small part is atmospheric evaporation discharge, and some of them emerge to the surface in the form of falling springs. The variation of its water content is greatly affected by the atmospheric precipitation, and it changes periodically with the seasonal variation. In view of the situation of less rainfall and lack of water resources, efficient water-saving measures such as micro-spraying and drip irrigation are adopted[17], and rainwater is collected through interception and drainage projects such as reservoirs, which can not only prevent soil erosion but also realize the reuse of water resources.

5.3 Problems and countermeasures of soil and water loss

From the point of view of soil and water conservation, it is considered that the project area does not belong to the dangerous area of collapse and landslide, the area prone to debris flow and the area prone to serious soil erosion and ecological deterioration. The construction process, supporting the corresponding temporary protection facilities, optimizes the layout of the project to prevent soil erosion [18]. For the unavoidable areas prone to soil and water loss, it is necessary to improve the prevention and control standards and engineering protection grades, improve the soil and water conservation measure system, optimize the construction technology, strengthen the control measures, reduce the disturbance of restoration and control, damage the surface and vegetation area, reduce the amount of excavation and filling, reduce soil and water loss, and maximize the protection and restoration of existing land and vegetation soil and water conservation functions.

6. Conclusion

In this ecological restoration and treatment, the actual restoration area was 324.97 hm²,91 geological hazard points were eliminated, and the restoration and greening area was 321.41 hm², of which 1002525

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shrubs were planted and 309.21 hm^2 of grass seeds were scattered, the survival rate of forest and grass vegetation reached 80%, the vegetation coverage increased to 43%, the service capacity of soil and water conservation increased by 10%, and the carbon sequestration capacity of vegetation increased by 0.1 $t/(hm^2 \cdot a)$. Mine ecological restoration work can restore the destroyed land resources, make them have the ability of sustainable use again, ensure the ecological security of the region, reduce the risk of geological hazards such as landslides and debris flows, and maintain the stability and balance of the ecosystem.

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Fund Project: Research on Key Technologies of ecological layer reconstruction in typical mining areas in the upper reaches of the Yellow River Basin

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