RESEARCH ON GEOLOGICAL ENVIRONMENT PROTECTION AND GEOLOGICAL DISASTERS CONTROL COUNTERMEASURES IN CHINA

Cheng Liu*

College of Artificial Intelligence, Dazhou Vocational and Technical College, Dazhou, Sichuan, 635001, China

liuchenglyl@163.com

Reception: 18/11/2022 **Acceptance**: 07/01/2023 **Publication**: 27/01/2023

Suggested citation:

L., Cheng (2023). **Research on geological environment protection and geological disasters control countermeasures in China**. *3C Empresa. Investigación y pensamiento crítico, 12(1)*, 186-205. https://doi.org/10.17993/3cemp.2023.120151.186-205

ABSTRACT

Geological disasters in mines, ecological environment and geology and geomorphology are closely bound up with each other. To reduce or avoid economic loss and to decrease the threat degree of geological disasters to life safety, the protection of geological environment are formulated in this study. Specifically, this includes taking mines that are dominated by thin bedded carbonate as the research objects. The goals of this study include prevention and control of geological disasters and protection of geological environment. The data are based on characteristics of geological strata in mines collected by the exploration, and combined with the characteristics of geomorphic environment, relevant rules aiming at the prevention and control of geological disasters. Then, pursuant to the selection of indicators, an evaluation system is constructed to verify the effectiveness of measures and strategies proposed, in which the score value is converted into the corresponding level to test the implementation effect of the measures and strategies proposed. Through comparing the changes of the utility levels before and after the implementation of measures and strategies proposed, it can be seen that the geological disaster levels of the five mining areas in the study region are respectively improved from the non-ideal levels V, IV, V, V, IV to II, I, I, II, II, with the tailings pond leakage times less than 4 times and collapse volume less than 5m3. And, the levels of geological environment are upgraded from levels IV, IV, IV, V, V to ideal levels II, II, II, I, II, accomplished by the vegetation coverage rate of the mine reaching more than 35%, as well as the recovery rate of exploitation and utilization rate of tailings both exceeding 85%, which indicates that the protection strategy proposed in this paper has good practicality and feasibility.

KEYWORDS

Geological characteristics; Geological disasters; Geomorphic environment; Linear weighted average method; Utility level; China

https://doi.org/10.17993/3cemp.2023.120151.186-205

PAPER INDEX

1. INTRODUCTION

China is rich in mineral resources with huge reserves, and is one of the few large resource countries in the world. The demand for mineral resources has been accompanied by rapid economic development and has a long history of mining development [1-2]. In recent years, the scale of mining has been rapidly developed and expanded, and the development of mining resources has strongly disturbed the geological environment [3-5]. Mining resources are providing resources for urban construction and social development, providing industrial food for the national economy, and accelerating economic and social development. However, it has also triggered a series of frequent geological disasters such as ground collapse, cave-in, and roofing, leaving behind many mining geological environment problems [6-7]. Especially, the mining geological environment problems caused by open-pit mining are particularly serious, which put the lives of people at risk and property loss, and become one of the important elements threatening ecological security [8-10].

With the rapid advancement of industrialization and urbanization and the implementation of ecological civilization construction strategy, along with the massive mining and range expansion of mines, the geological environment problems of mines have become increasingly prominent and the degree of ecological damage has become more and more serious, leading to serious geological disaster problems in mines [11-14]. Especially on abandoned mines around urban areas and within the visual range along important traffic arteries, the resulting destruction of vegetation, exposed hills and land damage have a bad impact on the city image and ecological environment [15-19]. Mine geological hazards have become a hot issue of public concern and social attention, and gradually evolved into a major obstacle to social and economic development, making the prevention of geological hazards and ecological environment restoration and management increasingly a common demand [20-22].

Therefore, it is urgent to vigorously implement comprehensive remediation of mining geological environment, repair the ecological environment of mining areas, improve the level of scientific land use and further improve the image of the city. This has not only become a major issue concerning urban development and ecological civilization construction, but also an effective means to eliminate geological disasters and guarantee the safety of people's lives and properties. Besides, it is also an important initiative to make full use of mining resources, promote economic development, ensure social stability and improve ecological civilization construction [23-25].

The environmental problems of mining areas have been widely concerned and valued by societies in various countries. For example, the literature [26] explored the intensive use of magnetic resonance populations, taking Yangquan, China, as an example, from the scientific connotation of magnetic resonance populations, and proposed a dynamic improvement path to enhance the intensive use, thus filling the gap in this field. The background conditions of the mine and the basic cases of the corresponding mining enterprises, both of which are indicators presented by the resource itself in the process of converting minerals into useful products, constitute the basic framework for identifying and enhancing the intensive use of mineral

 https://doi.org/10.17993/3cemp.2023.120151.186-205

resources. The results show that mining enterprises are the core of intensive utilization, the mining recovery rate contributes most to the intensive utilization of resources, and the mine size does have an impact on the intensive utilization of resources, but the impact will gradually decrease when a certain size is reached. Therefore, from the perspective of enterprise governance, a corresponding dynamic improvement path is adopted in an attempt to increase the degree of intensification. In the literature [27], a Bayesian belief network probabilistic prediction framework was developed to support practical and cost-effective decision making for decentralized disposal management. This approach allows the incorporation of expert knowledge in cases where data are insufficient for modeling. The performance of the model was validated using field data from actively managed mine sites and was found to be consistent in predicting soil erosion and ground cover. In the literature [28], stability studies were carried out for weathered toxic sand mine wastes of amorphous iron arsenate/pyrochlore using different doses of modifiers, as determined by X-ray diffraction and polarized light microscopy, to evaluate the effectiveness of such treatments using batch and column leaching methods. Under the equilibrium conditions imposed by the applied standard batch leaching tests, both treatments achieved significant reductions in leachable arsenic concentrations under their optimal conditions, making the mine wastes acceptable in controlled landfills as defined by international legislation. The literature [29] investigated dust pollution in open-pit coal mines in cold regions and explored its main influencing factors. The dust pollution characteristics were determined by statistical analysis, and the main influencing factors of dust concentration in different seasons were calculated using the integrated gray correlation. A hybrid single-particle Lagrangian integral trajectory model was used to simulate the dust pollution from the mine to the surrounding area. Based on the results of the study, an optimal mine design strategy was designed to better control dust in mining and adjacent areas, especially in winter. The literature [30] focused on underground mining in Pakistan, using the decision matrix risk assessment method to assess events based on their severity and probability, and based on the results of the resulting study, proposed management measures that would help avoid mining accidents by applying occupational safety and health regulations issued by the Ministry of Mines. The above approach is mainly manifested in the shift from static implementation of environmental policies and standards to the implementation of dynamic management. There is a shift from a single management tool to strengthening cooperation between government departments and mining companies and enhancing the environmental protection capacity of mining companies. However, with the huge impact of mining environmental problems on economic development, social progress and ecological environment, there is still a need to continuously carry out research on mining environmental problems.

The large-scale development and utilization of mineral resources has caused serious geohazards and geological environmental problems, and there is a certain connection between this problem and geomorphological feature. Based on this, this paper develops a geohazard prevention and control measure and geological environmental protection strategy consisting of three strategic points each, based on the geological and geomorphological features of the study area. Using the United

https://doi.org/10.17993/3cemp.2023.120151.186-205

Nations Commission on Sustainable Development's menu-based multi-indicator type indicator system approach, an evaluation indicator system for verifying the specific effectiveness of prevention and control measures and protection strategies is constructed for the reference of management and mining enterprises. The ultimate goal is to minimize the damage to the geological environment of mines and to restore it gradually.

2. GEOLOGICAL AND GEOMORPHOLOGICAL CHARACTERISTICS OF THE STUDY AREA

A mine with thin-layered carbonate rocks as the main mineral resource was selected as the study object, and the geological and geomorphological features of the mine are shown in Figure 1. The stratigraphy of the study area mainly includes Devonian, Carboniferous, Permian and Triassic. According to the lithological characteristics, the stratigraphy of the mine area can be divided into two sets of rock systems, namely the Triassic mud and sandstone rock system, and the carbonate rock system below the Triassic system. The primary sedimentary chain soil deposits are distributed in the stratum of carbonate rock system on the upper side, underlain by thick-layered carbonate rocks, and the rocks below the primary sedimentary chain soil deposits are light in color, pure and with little lithological variation. The rocks above the primary sedimentary silver earth ore layer are mostly thin-layered carbonate rocks with dark color, high lithological variation and muddy interlayer. The Triassic siltstone is mostly a fine-grained shoulder structure with tuffaceous components. The lithological characteristics of the mine stratigraphy can be summarized as the complete development process of the opening, expansion, interrupted surface and closing of the Right River Basin. The Right River Basin opened in the middle Devonian, and no pre-Devonian stratigraphic basement is exposed in the mine area, which cannot reflect the characteristics of the stratigraphic interface of the basin opening. The petrographic situation of the stratigraphy of the mine area indicates that the mine has a terrace tectonic nature and basically maintains a terrace shallow water depositional environment from the Devonian, although it also shows a temporary increase in water depth, but does not change the terrace nature. Therefore, the geography of the area generally belongs to a terrace environment in 31the Right River Basin.

The selected mines are located from southwest to northeast of the Right River, Bujian River and Pingzhi River, all of which are oriented in a northwesterly direction, forming a pattern of distribution between karst landforms and river landforms. On the southwest side of the Right River are the No. 1 and No. 2 mines, between the Right River and the Bujian River is the No. 3 mine, and between the Bujian River and the Pingzhi River are the No. 4 and No. 5 mines. The mining area is mainly divided into two types of landforms, karst and river valley. The karst landforms are mainly composed of mountainous positive terrain, and the river valley landforms are distributed in the negative terrain of the basin. The geomorphology of the mine area is mainly controlled by lithology and tectonics, and constitutes a combination of lithologic and tectonic geomorphology. The lithological control shows that the karst landform is

https://doi.org/10.17993/3cemp.2023.120151.186-205

developed in the carbonate stratum of the former Triassic, and the river landform is developed in the Triassic mudstone stratum. The tectonic control shows that the karst landforms are developed in the back-sloping core and the fluvial landforms are developed in the diagonal core. Since the geological and geomorphic features of the mine have not been discussed much in previous studies, the geology and geomorphology of the target area are combined in a comprehensive study to lay the foundation for the development of subsequent geological hazard prevention and control measures and geological environmental protection strategies.

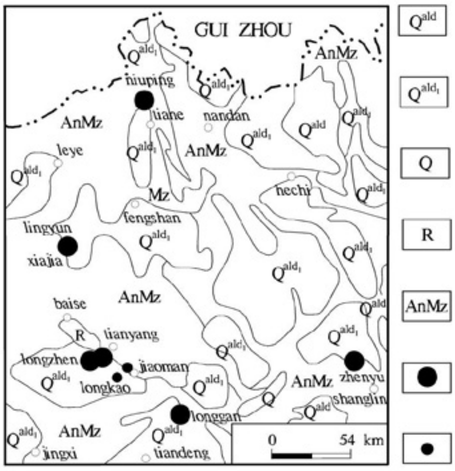


Figure 1 Schematic diagram of the geological features of the study area

3. MINE GEOLOGICAL HAZARD PREVENTION AND CONTROL AND GEOLOGICAL ENVIRONMENTAL PROTECTION STRATEGY DESIGN

Based on the geological features of the study area, the geological hazard prevention and control measures and geological environmental protection strategies shown in Table 1 are formulated.

Table 1 Mine geohazard prevention and control and geological environmental protection strategy

Strategic objectives	Strategy points
Geological disaster prevention and control	Disaster monitoring
	Landslide prevention and control
	Prevention and control of sudden water
Geological environmental protection	Fulfill regulatory responsibilities in accordance with the law and implement the main responsibility of enterprises
	Improve the technology content and level of mine environmental protection
	Exploring new ways to develop and manage mines

https://doi.org/10.17993/3cemp.2023.120151.186-205

3.1. RULES FOR GEOLOGICAL HAZARD PREVENTION AND CONTROL MEASURES IN MINES

(1) Mine geological disaster monitoring is the basic work in mine geological disaster prevention and control. The main purpose of mine geological disaster monitoring is to understand the changes of mine geological environment in time and space, analyze the relationship between mining and mine geological environment changes, and provide basic reference information for formulating mine geological environmental protection measures and improving mine geological environment. In the specific mine geological disaster prevention and control process, reasonable and effective monitoring technology should be used according to the needs of mine geological environment monitoring, and mine terrain monitoring instruments should be developed. Introduce advanced mining geological environment monitoring technology, such as modern information collection technology, Zigbee wireless networking technology, modern network communication technology, etc., to effectively monitor and prevent mining geological disasters, so as to reduce the casualties and economic losses caused by mining geological disasters.

(2) In order to effectively manage mining geological hazards, it is necessary to do a good job of preventing and controlling crumbling. First, reduce the height of the steps. For areas where there are a lot of weathered and broken or soft structural surfaces, the self-weight should be reduced by using measures to lower the height or slow down the slope, and the height of the steps should be controlled within 9 meters. Second, interception of rolling rocks. For areas where rolling rocks occur frequently, not only do you need to set up warning signs, but you also need to set up intercepting structures at the foot of the slope. For example, production stripping can be dumped to stop rolling rocks and debris at a location away from the foot of the slope. Thirdly, when horizontal blasting operations are carried out at the end of mining, it is necessary to use slope residual cracking blasting and hole-by-hole seismic control blasting technology to alleviate blasting damage to the slope, thereby preventing the generation of crumbling disasters.

(3) The problem of sudden water is one of the key problems in mining geological hazards, which requires corresponding prevention and control measures, which can be carried out in the following aspects. First, mine-waterproofing. In the process of mine waterproofing, measures need to be taken to prevent water from flowing into the mine and to effectively control the inflow. In this way, it can reduce the amount of water gushing into the mine, save the cost of drainage, reduce the cost of coal production and prevent water damage from the root of the problem. Second, mine drainage. In order to remove mine water, drainage ditches, water bins and pumps in mine tunnels can be used.

3.2. MINE GEOLOGICAL ENVIRONMENTAL PROTECTION STRATEGY RULES

(1) In order to effectively protect the mine geological environment, an annual treatment plan should be implemented and a sound monitoring network for the mine geological environment should be established. Dynamic monitoring of mine geological environment, regular reporting of mine geological environment to the competent natural resources department at the county level where the mine is located, and submission of real monitoring information. In addition, the relevant departments should target the mining right holder to fulfill the obligations of mine geological environmental protection and treatment and restoration. And establish a system of supervision and inspection, and use the results of supervision and inspection as the procedure for applying for the continuation, change and transfer of mining rights. In addition, the sampling of corporate information social disclosure should be a key review. The relevant departments also need to use remote sensing monitoring data of the mining geological environment to detect and dispose of illegal mining practices in a timely manner.

(2) Rely on scientific and technological progress and technological innovation to improve the level of geological environmental protection in mines. Strengthen the development and application of new technologies, new techniques and new methods, increase investment in science and technology, and promote technological progress in comprehensive utilization of resources. In addition, funding should also be strengthened for research fields such as mining environmental geology. Research on the impact of mine development on the geological environment and prevention and control technologies, research on the treatment of the three wastes of mining industry and waste recovery and comprehensive utilization technologies, and research on advanced mining and selection technologies and processing and utilization technologies, so as to achieve the purpose of protecting the geological environment of mines.

(3) Comprehensive consideration of mineral resources planning, mine geological environment protection and management planning, ecological environment planning, etc. Government departments should give priority to the geological environment management of mines within the visual range of the "three zones and two lines". For the remaining scattered resources, the mountain does not have the conditions for restoration and there are potential safety hazards, if it is in line with the mineral resources plan, the mining rights should be reset. If it does not conform to the mineral resources plan, it can be disposed of by the relevant government department where the mine is located in accordance with the principles of government-led, expert-evaluated, strict control and clear responsibility, and the corresponding residual resources will be used for geological environment treatment.

https://doi.org/10.17993/3cemp.2023.120151.186-205

4. EVALUATION SYSTEM FOR THE UTILITY OF GEOLOGICAL DISASTER PREVENTION AND CONTROL AND GEOLOGICAL ENVIRONMENTAL PROTECTION STRATEGIES

In order to effectively and accurately analyze the specific utility of the developed geohazard prevention and geological environmental protection strategies for the study area and to establish a reasonable evaluation index system, the prerequisite is to solve several problems. The first is the scientific nature of the indicators. The second is the operability and measurability of the indicators. The third is the conciseness of the metrics. Based on the above starting point, after fully considering the impact of the geological features of the mine on geological hazards and geological environment, reference is made to the sustainable development index system proposed by various units and departments. And using the method of the United Nations Commission on Sustainable Development menu-type multi-indicator type indicator system, it is proposed to construct the evaluation index system of mine geohazard condition and geological environmental level from two major first-level indicators and 13 second-level indicators. Thus, the specific utility of geological disaster prevention and control and geological environmental protection strategies can be verified. The weights of the indicators in this index system can also be obtained through hierarchical analysis [31-33]. For details, see Table 2.

Table 2 Evaluation system of the utility of geological disaster prevention and control and geological environmental protection strategies

Level 1 indicators	Secondary index
Level of geological hazards	Collapse volume/m^3
	Landslide volume/m^3
	Debris flow material source volume/t
	Ground collapse range/m^2
	Number of tailing pond leaks/time
Level of geological environment	Water quality index
	Soil quality index
	Vegetation coverage rate/%
	Land leveling degree
	Mining recovery rate/%
	Tailings utilization rate/%
	Mineral processing water reuse rate/%
	Ecological restoration rate/%

A percentage system was implemented, and the linear weighted average method was used for the calculation of the scores [34-35]. Based on the calculation principles

https://doi.org/10.17993/3cemp.2023.120151.186-205

and formulas of the weighted average method, a linear calculation model was established in turn. Based on the assessment team members' weights, the score of each index element in the lowest level index was calculated, and the calculation model was.

$$Q_j = \sum_{i=1}^{n} P_{ij} \cdot Q_{ij} \qquad (1)$$

Where P_{ij} represents the rating of each member of the group for level j indicators; Q_{ij} represents the weight of the assessment group members for each indicator element of level j indicators; i represents the number of assessment group members, $i = 1, 2, ?n$.

Based on the index content weights, the weighted average score of each level index is calculated from bottom to top, and the calculation model is:

$$S_w = \sum_{c=1}^{n} P_{cw} \cdot Q_{cw} \qquad (2)$$

Where P_{cw} represents the score of each indicator in level w; Q_{cw} represents the weight of each indicator in level w; c represents the number of indicators, $c = 1, 2, ?n$.

The index is scored according to the description of the index, and the score is written in the score column, and the full score of each level 2 index is 100. The score of each level 1 indicator can be calculated by adding up the scores of all level 2 indicators. Among them, the degree of geohazard is a negative indicator, and the smaller the value of the second-level indicator, the lower the degree of geohazard, and the larger the value of the first-level indicator. The specific scoring method for each indicator is described below.

(1) Collapse volume: full marks are given when the volume of collapse is below 5m^3, otherwise 0~90 marks are given as appropriate.

(2) Landslide volume: when the volume of landslide is less than 10m^3, full marks will be given, otherwise 0~90 marks will be given as appropriate.

(3) Mudslide source volume: full marks are given when the mudslide source volume is less than 3t, and 0~90 marks are given if the requirement is not met.

(4) The scope of ground collapse: when the ground collapse range of less than 6m^2 scored full points, otherwise 0 ~ 90 points as appropriate.

(5) tailing pond leakage number: full marks when the tailing pond leakage number is less than 4 times, otherwise 0~90 marks will be given as appropriate.

(6) Water quality index: full marks when the water quality index is above 7.9, and 0~90 marks when the requirement is not met.

(7) Soil quality index: full score when the soil quality index is greater than 8.2, and 0~90 points as appropriate when the requirement is not met.

(8) Vegetation cover: full marks are given when the vegetation cover of the mine area reaches 35% or more, otherwise 0~90 marks are given as appropriate.

(9) Land leveling: full marks will be awarded when the land leveling exceeds 9, otherwise 0~90 marks will be awarded as appropriate.

(10) Mining recovery rate: full marks will be awarded when the mining recovery rate is above 85%, otherwise 0~90 marks will be awarded as appropriate.

(11) Tailings utilization rate: full marks are given when the tailings utilization rate is above 85%, and 0~90 marks are given as appropriate when the requirement is not met.

(12) Repeated utilization rate of mineral processing water: full marks will be given when the repeated utilization rate of mineral processing water is more than 80%, otherwise 0~90 marks will be given as appropriate.

(13) Ecological recovery rate: the ecological recovery rate of the geological environment is relative to the ecological damage. The destruction of the ecology of the mining environment can be understood as a change in the structure, degradation or loss of function of the ecosystem, and disturbance of relationships. Ecological restoration is about restoring the rational structure, efficient functions and harmonious relationships of the ecosystem [35]. Ecological restoration is essentially the process of orderly succession of the destroyed ecosystem, a process that makes it possible to restore the ecosystem to its native state [36]. However, due to the complexity of natural conditions and the influence of human society's orientation toward the use of natural resources, ecological restoration does not mean that the restored ecosystem can or must be left in its original state in all cases. Ecological restoration rate refers to the percentage of the restored area to the total area of the abandoned land after the implementation of ecological engineering for those abandoned land caused by mining stripping land, waste mine pits, tailing pits, tailings, slag, gangue, and wastewater sediment of ore dressing and washing. For the historical ecological problems, the indicator reaches 30% or more full marks [37]. For the area of mining and restoration at the same time, full marks will be given when the indicator reaches 70% or more; otherwise, 0~90 marks will be given as appropriate.

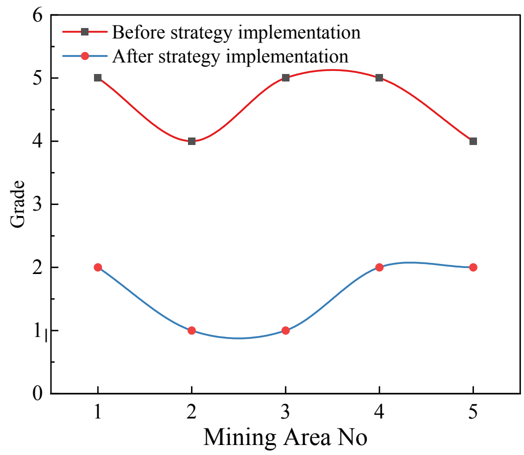
To sum up, when the final score range of the primary index is 90~100, the geohazard situation and geological environmental condition of the study target are excellent, and the disaster level and environmental level are set to class I [38-39]. It indicates that the strategy utility can be given full play, and has played an excellent prevention and protection effect. When the final score range is 80~90, the geohazard situation and geological environmental condition of the study target is good, and the grade is set to class II. It indicates that the prevention and protection effect of the strategy is strong. When the score range is 65~80, the geohazard situation and geological environmental condition of the mine is average, and the level of disaster and environmental level is set to class III. This indicates that the strategy has certain effect of geological disaster prevention and geological environmental protection. When the score range is 55~65, the geohazard situation and geological environmental condition of the area is poor, and the level is set to class IV, which

https://doi.org/10.17993/3cemp.2023.120151.186-205

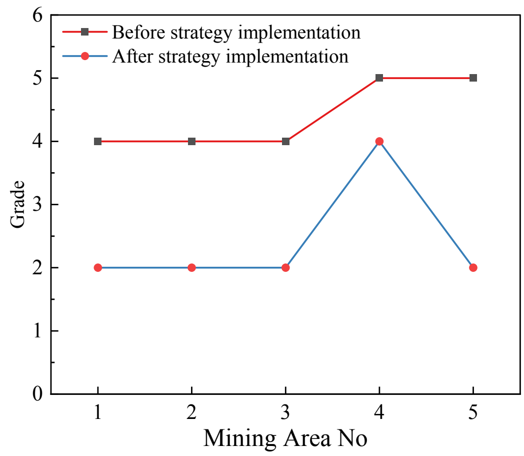
means the developed strategy is not able to manage and protect the geohazard and ecological environment well. When the score range of the primary index is 0~55, the target's geohazard situation and geological environmental condition is extremely poor. The hazard level and environment level are set to class V, which means the developed strategy basically does not have any effect on the management and protection of geological hazards and ecological environment in the study area.

5. ANALYSIS AND DISCUSSION

By consulting the statistical yearbook of the city where the mine is located, the data of each index of the five divisions of the target mine were collected one year before and one year after the implementation of the strategy. After scoring with the utility evaluation system, the scores of geohazard degree and geological environmental level before and after the implementation of the strategy were obtained. After dividing the scores according to the levels, the utility evaluation results of the prevention and protection strategies were obtained as shown in Figure 2.



(a) Geological disaster prevention and control utility



(b) Utility of geological environmental protection

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Figure 2 Schematic diagram of the utility of geohazard control and geological environmental protection strategies

By comparing the changes in the level of geological hazards before and after the implementation of the strategy in Figure 2(a), it can be seen that the level of geological hazards in the five mining areas in this study area before the geological hazard control measures were carried out were V, IV, V, V and IV levels. This indicates that the mine is characterized by geological lithology such as large changes in Devonian, Carboniferous, Permian and Triassic lithologies, increased muddy interlayers, fine-grained shoulder structure, tuff-bearing components and other geological lithologies, resulting in a large footprint for crumbling and slag disposal and a large impact area for ground collapse, leading to a relatively serious degree of geological disaster.

Through targeted and reasonable geological hazard prevention and control measures for different mining areas, the level of geological hazards in the target area is upgraded to class II, I, I, II and II.

For small collapse hazards in No.1 mine, the slope is cut to reduce the load and remove dangerous rocks to release the danger, and the large collapse is reinforced by anchor spraying method as a whole, paying attention to strengthen drainage. The surface of the collapsed mining area is re-leveled, the collapse pits and cracks are filled in, and interception ditches and drainage ditches are constructed to prevent the ground from pouring into the mine and causing landslides. The level of geological disaster was changed from V to II.

For the No. 2 mine, advanced mining technology is implemented, such as: using waste rock, slag or tailing sand to fill the mining area, which controls and slows down the surface subsidence and the collapse behavior and magnitude of the mining area, and also reduces the problem of massive land encroachment by slag and tailing sand, which changes the level of geological hazard from IV to I.

Due to the poor background conditions of the geological environment in mine site No. 3, the catchment area, landslide volume and relative height difference are large, and the tailings pond leakage breach is obvious. Therefore, anti-slip rock stacks, anti-slip retaining walls, anti-slip piles and anti-slip piles were constructed at different locations of the landslide body in the mine. The overall anchoring measures were taken to improve the friction and shear strength of the landslide body and enhance the overall stability of the landslide body. And plant trees and grass on the surface of the landslide body to prevent soil erosion and mudflow on the slope surface. During the operation of the tailing ponds, supervision and management were strengthened, and proper operation was carried out to prevent tailings sand overflow and dam failure more effectively. For tailings ponds that have breached or have the potential to breach, works were arranged to repair and reinforce them. When building new tailing ponds, extra attention was paid to site selection, and tailing ponds were built at locations higher than the highest flood level in the calendar year, and it was explicitly prohibited to dig and build tailing ponds on existing river floodplains. The tailing ponds were designed with safety and stability in mind, ensuring that the drainage and flood control systems were complete, and that quality and quantity were maintained during construction to prevent a recurrence of the dam failure and change the geological hazard level from V to I.

The main problem of No. 4 mine is the large size of the landslide, and part of the shed is built under the slag pile. When heavy rain comes, it will cause casualties, and there is a huge potential danger of collapse above the shed. Therefore, measures were taken to reduce the height or slow down the slope to reduce the self-weight, and the height of the steps was controlled within 9 meters, and intercepting structures were set at the foot of the slope, which greatly solved the problem of landslide and reduced the degree of geological disaster. The level of geological hazard was changed from class V to class II.

No. 5 mine is a large state-owned enterprise, according to the demand of mine geological environment monitoring, using reasonable and effective monitoring technology, developing mine terrain monitoring instruments, introducing advanced mine geological environment monitoring technology, constructing slag mudflow and accident pool collapse potential hazard management project, effectively monitoring and preventing mine geological disasters, controlling the magnitude of ground collapse, not only basically eliminating the previous existence of slag mudflow and accident pool collapse potential hazard, but also reducing the casualties and economic losses caused by mine geological disasters, changing the level of geological disasters from class IV to class II.

From the change of geological environmental level grade before and after the implementation of geological environmental protection strategy (see Figure 2(b)), it can be seen that before the implementation of geological environmental protection strategy, the geological environmental level grades of the five mining areas were class IV, IV, IV, V and V, with poor ecological and environmental benefits. And one year after the implementation of the geological environmental protection strategy, the level of geological environmental level in the study area increased dramatically to class II, II, II, I, II. It shows that the protection strategy has given full play to its effectiveness and has excellent protection and restoration effects. It has greatly improved the ecological environment of the mine and brought the ecology into balance gradually.

For example, the No. 1 mine area has a high number of mining pits, resulting in low vegetation coverage, serious soil erosion and high content of heavy metals in water and soil. By implementing the annual treatment plan, a sound monitoring network of mine geological environment is established. Dynamic monitoring of the geological environment of mines, regular to the mine location of the county-level natural resources authorities, report the geological environment of mines, submit real monitoring information. Using the remote sensing monitoring data of mine geological environment, illegal mining behaviors are detected and disposed of in a timely manner. It not only effectively protects the geological and ecological environment of mines, but also makes the mining and other activities of mines more standardized, so that the level of geological environment level rises from class IV to class II.

https://doi.org/10.17993/3cemp.2023.120151.186-205

In dealing with the geological environment of No. 2 mine, we based on the results of the surface engineering treatment. Considering the mineral resources planning, mine geological environment protection and treatment planning, ecological environment planning, etc., the geological environment treatment of the mine within the visual range of "three zones and two lines" was completed as a priority. The geological environment level of the mine has been upgraded from class IV to class II.

The heavy metal pollution of water and soil in No. 3 mine is more serious. On the basis of the project to raise and reinforce the tailing reservoir dike, the tailing sand was covered with soil 0.5~0.8m thick. Then trees, grass and crops were planted, so that the ecosystem of the mine was well protected. And gradually restored to a benign ecological level, so that the level of its geological environmental level rose from IV to II.

In response to the low vegetation cover in mine 4, the same conservation strategy as in mine 3 was adopted. Trees, grass and crops are planted in the 0.5~0.8m thick overburden. After mining, treatment and protection at the same time, the mine is reclaimed and re-greened in time to change the vicious ecosystem structure, restore the ecological function and stabilize the ecological balance. Make the ecosystem structure of the mine more reasonable, more efficient in function and more coordinated in relationship. Eventually, the level of geological environment will be upgraded from V to I.

For mine site No. 5, the accident pond is used for primary sedimentation treatment of mine pit wastewater. The suspended mineral dust in the water is retained and the pollution of surface water is reduced. A water purification system is also specially designed for the drainage outlet of the tailing pond to realize the recycling of water resources and the recovery of residual gold. Through the treatment of the three mining wastes and waste recycling, the purpose of protecting the geological environment has been truly realized, and the level of geological environment has been upgraded from V to II.

6. DISCUSSION

The geohazard prevention and control measures and geological environment protection strategies proposed in this paper for the geological features of mines, although certain research results have been achieved, there are still many shortcomings, mainly containing the following points.

(1) Only the geological and geomorphological characteristics of the study area were analyzed, which is not comprehensive. In future research, it is necessary to face several mines, summarize the geohazard prevention and control measures and geological environment protection methods of different mines, and propose remediation strategies suitable for universal mines.

(2) The geohazard prevention and control measures are mainly based on the management of geological hazards such as landslides, landslides and debris flows, and the geological environment protection strategy is mainly based on restoring the

https://doi.org/10.17993/3cemp.2023.120151.186-205

quality of water and soil, expanding vegetation coverage and improving resource utilization. Although the ecological environment of the mine is protected to a certain extent, the ways and means are too single, so in the future research, we should consider many aspects and integrate multiple perspectives to explore a more systematic protection scheme.

7. CONCLUSION

The large-scale development and utilization of mineral resources has made human beings enjoy the benefits brought by natural resources while also suffering from a series of bitter consequences such as environmental pollution, resource destruction and ecological degradation. Especially, some local mining areas with large-scale predatory mining have caused serious geological disasters and geological environment problems. Therefore, the research on the prevention and control of geological disasters and the protection of geological environment seems to be urgent. Therefore, based on the geological features of the study area, this paper formulates the details of the prevention and control measures for mine geological hazards and the protection strategy for mine geological environment, and uses the hierarchical analysis method to obtain the index weights of the utility evaluation system. The utility of the proposed measures and strategies was verified through the scoring results and ranking of the linear weighted average method, and the following research findings were obtained.

(1) According to the needs of mine geological environment monitoring, use reasonable and effective monitoring technology, develop mine terrain monitoring instruments, and introduce advanced mine geological environment monitoring technology, which can effectively monitor and prevent mines geological disasters.

(2) For the collapse phenomenon of geological disasters, the ground collapse magnitude can be greatly controlled by reducing the height of steps, intercepting rolling rocks, using slope residual cracking blasting and hole-by-hole seismic reduction control blasting technology, and preventing the occurrence of slope erosion, slope debris flow, tailing sand spill and dam failure. The volume of landslide is less than $10m^3$ and the ground collapse area is less than $6m^2$.

(3) the establishment of a sound mine geological environment monitoring network, regular to the county-level natural resources departments in charge of the mine location, report the mine geological environment. It can obtain the impact of mine development on the geological environment in real time and take relevant initiatives in time to increase the greening coverage of the collapse area, protect the ecosystem and restore it to a benign ecological level, and optimize the geological environment level from class IV, IV, IV, V, V to class II, II, I, II respectively. Raise the water quality index and soil quality index to above 7.9 and 8.2 respectively.

https://doi.org/10.17993/3cemp.2023.120151.186-205

8. DATA AVAILABILITY STATEMENT

The original contributions presented in the study are included in the article/supplementary material, further inquiries can be directed to the corresponding author.

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10. CONFLICT OF INTEREST

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.