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Evaluation of Mine Geological Environment of Guqiao Coalmine

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Abstract

The geological environment is important for the development of coal enterprises. In the Guqiao coalmine, the information of coal mining subsidence, terrain landform, coal gangue utilization, mine water treatment and several on-site investigations have been analyzed. It holds that its geological environment can be evaluated from three aspects, i.e., geological disasters, terrain and landform destruction, and influence on water and soil environment. The results show that mining activities have serious impacts on geological disasters and terrain landform, while lighter impacts on the water and soil environment. According to the research results, a set of corresponding governance strategies are given. The findings can provide theoretical support for the geological environmental protection and restoration of the Guqiao coalmine.

Keywords

Geological Environment, Coal Mining Subsidence, Terrain Landform, Water and Soil Environment

1. Introduction

Coal resources play a vital role in the development of the national economy (Hatherly, 2013). Inevitably, coal mining process has negative effects on the geological environment, such as mine geological disasters (Zhi-fei & Hai-ming, 2008), land destruction (Kalkreuth et al., 1991), solid waste dumping and mine water discharge (Choubey, 1991), which are very unfavorable for People's production and living in the coalmines. Under the situation of coal-based energy structure (Finkelman et al., 2002; Dai & Finkelman, 2020), neglecting these problems will certainly lead to the gradual deterioration of the geological environment.

So far, many countries attach great importance to geological environmental problems, and are committed to achieving simultaneous completion of mining

and treatment (Thomas & Thomas, 2002). Furthermore, this issue has been highly valued by scholars. For instance, Cao et al. (2007) established the correlation matrix of assessment indicators to analyze the mine geological environments. Si et al. (2010) integrated multiple indicators to analyze the environmental sustainability of coalmines hieratically. Silva et al. (2011) focused on coal mining drainage to declare the environment health problems. Lei and Bian (2014) balanced the several key environmental elements to reduce their impacts. Yang et al. (2018, 2019) discussed the eco-geological environment problem of coalmines based on multi-factor weights analysis and fuzzy classification ideas. Liu et al. (2018) established a zoning mathematical model with variable-weight theory to assess the eco-geological environment of the Yushenfu coalmine.

The Guqiao coalmine is a large-scale and multi-coal mining area of China, which covers about 9200 square kilometers. By the end of 2020, its remaining workable reserves is 790 million tons, and its remaining service life is about 67 years. The increasing depth of mining and subsidence will strengthen the worsening of the geological environments. In order to ensure the coordinated development of coal mining and environment treatment, it is very necessary to assess the mining geological environment.

The rest of this article is organized as follows. Section 2 introduces several indicators for assessing the geological environment of the Guqiao coalmine. Section 3 divides the mining area according to the degree of impact on geological environment. Section 4 presents the research results and puts forward some suggestions. Section 5 concludes this article.

2. Mine Geological Environment Assessment Index

This section mainly introduces three indicators for assessing the geological environment of the coalmine: geological disasters, terrain and landform destruction, and influence on water and soil environment.

2.1. Geological Disasters

Coal mining can induce massive subsidence, ground fissures, landslide, debris flow and other geological disasters. The total research area has a flat terrain with high stability. Since production, the major geological disaster in such area is subsidence, and other geological disasters are not obvious.

Mining underlying coal will destroy the original mechanical balance of the rock, which can lead to the deformation, destruction and movement of overlying strata. When the mining range reach the certain degree, such movement and destruction will extend to the surface, resulting in large-scale subside or collapse of the surface, called subsidence. According to the current situation and the degree of damage of subsidence, the area affected by subsidence can be divided into the light part, the severe part, and the more severe part (details seen in Table 1).

Table 1. Statistics on the impact of geological disasters.

Influence level	Subsidence depth (D)	Mined-out area	Total
Light	D ≤ 0.5 m	677.63 hm^2	
Severe	0.5 m < D ≤ 1.5 m	311.59 hm^2	2224.25 hm^2
More severe	D ≥ 1.5 m	1235.03 hm^2	

2.2. Terrain and Landform Destruction

The performance of mining enterprises are inseparable from excellent infrastructure. And then, the Guqiao coalmine has constructed several industrial plazas including the Central one, the Nanfengjing one and the Dongfengjing one, covering a total area of about 159.25 hectares (hm^2). These facilities have changed the original geomorphic types, and have a serious impact on the geological environment.

During the mining of underlying coal, the corresponding surface gradually sinks, which may lead to the relocation of ground towns and the destruction of cultivated land. It has greatly influential on the surface landform and terrain elevation. And hence, the original terrain and landform of the mining area have been changed. According to the impact of subsidence and surface infrastructure, the area affected by terrain and landform destruction can be divided into the light part, the severe part, and the more severe part (details seen in Table 2).

2.3. Influence on Water and Soil Environmental

The solid waste and sewage generated from coal mining have adverse effects on the water and soil environment. Solid waste mainly refers to coal gangue, coal slime, and domestic garbage. Sewage mainly refers to mine water and domestic sewage from industrial plazas.

2.3.1. The Impact of Solid Waste on Water and Soil Environment

The Guqiao coalmine produces about 2.22 million tons of coal gangue every year. They are mainly used for backfilling subsided areas, roads, dams and as raw materials for burning bricks and building materials. All coal slime is to be sold, without discharged. The household garbage is collected separately and handled by the local environmental sanitation department. Therefore, only coal gangue may have an impact on the water and soil environment of the total research area.

In order to capture the impact of coal gangue on the water and soil environment, we do a static immersion test, and the result is shown in Table 3.

From extraction toxicity testing of coal gangue and "Hazardous Waste Identification Standards for Extraction Toxicity (GB5085.3-2007)", it can be known that, the coal gangue produced in the Guqiao coalmine not belongs to hazardous wastes but a general industrial solid waste. In addition, the concentration of various pollutants in the solid waste leachate is lower than the requirements of the first-class pollutant discharge standard or the second-order discharge limit in the "Integrated Wastewater Discharge Standard (GB8978-1996)".

Table 2. Statistics on the impact of terrain and landform destruction.

Influence level	subsidence area	Central	Nanfengjing	Dongfengjing	Total
Lightly	677.63 hm^2	-	-	-	677.63 hm^2
Severely	311.59 hm^2	-	-	-	311.59 hm^2
More severely	1235.03 hm^2	129.89 hm^2	21.96 hm^2	7.4 hm^2	1394.28 hm^2

Table 3. Results of extraction toxicity of coal gangue in Guqiao coalmine (Unit: pH is dimensionless; total Cr, As and Hg are ug/L; and the rest are mg/L).

Factors	pH	Cu	Zn	Pb	Cd	Ni	Total Cr	As	F	Hg
Value	8.3	0.04	0.24	-	-	0.08	27.8	21.4	1.16	0.71
Threshold	-	0.02	0.01	0.03	0.01	0.03	0.7	0.0001	0.05	0.05

We do a set of soil monitoring in two monitoring stations of the Guqiao coalmine—Tangjia and Baitangmiao station backfilled with coal gangue (details seen in Table 4). The results reflect that the soil environmental quality can satisfy the second level of the "Soil Environmental Quality Standards (GB15617-1995)".

In summary, the solid waste produced by the Guqiao coalmine has a relatively minor impact on the water and soil environment.

2.3.2. The Impact of Sewage on Water and Soil Environment

The mine water flow rate is 2325 m^3/d (resp. 2976 m^3/d) and the sewage discharge rate is 2000 m^3/d (resp. 1000 m^3/d) in the central (resp. south) area of Guqiao coalmine. Correspondingly, there is a mine water treatment station with a processing capacity of 20,000 m^3/d (resp. 12,768 m^3/d) and a domestic sewage treatment station with a processing capacity of 2500 m^3/d (resp. 1200 m^3/d) in the central (resp. south) area. In this case, the demand for the purification treatments of mine water and domestic sewage can be satisfied. After purified (details seen in Table 5), on the one hand, the mine water can serve multiple purposes, such as coal preparation, ground greening, and dust reduction; on the other hand, the domestic sewage will be discharged to a nearby river.

It can be seen from Table 5 that the qualities of the purified mine water and domestic sewage agree with the requirements of the first-level standard of the "Integrated Wastewater Discharge Standard (GB8978-1996)", which has a slight impact on the water and soil environment of the research area.

3. Obtaining Partitions According to the Influence on Geological Environment

According to the above indicators, the current status of the geological environment in the Guqiao coalmine can be classified with the Appendix E "Classification of Influence on Mining Geological Environment" of "Guidelines for the Preparation of Mining Geological Environmental Protection and Recovery Treatment Plan (DZ/T 0223-2011)", as shown in Figure 1.

Table 4. Soil monitoring in the Guqiao coalmine area backfilled with gangue (Unit: pH is dimensionless, and the rest are mg/L).

Samples	Station	pH	Pb	Cu	As
01	Tangjia	7.81	39.5	32.5	12.85
02		8.06	34.9	33.4	13.09
03	Baitangmiao	7.93	43.1	28.7	12.50
04		8.01	33.0	28.2	10.80
Level 2 standard of GB15618-1995		>7.5	≤350	≤100	≤25

Table 5. Quality monitoring of mine water and domestic sewage after purification (Unit: pH is dimensionless, and the rest are mg/L).

Test items Water samples	pH	Suspended matter	Chemical oxygen demand	Ammonia nitrogen
Mine water 1 # in the central	8.09	7.5	<10	<0.025
Mine water 1 # in the south	8.56	<4	<10	<0.025
Domestic sewage 1 # in the central	8.26	<4	<10	0.21
Domestic sewage 1 # in the south	8.25	<4	<10	2.54
Mine water 2 # in the central	8.27	14	<10	0.12
Mine water 2 # in the south	8.61	10	<10	0.14
Domestic sewage 2 # in the central	8.43	13	<10	0.12
Domestic sewage 1 # in the south	8.11	13	12	6.11
Mine water 3 # in the central	8.07	4	<10	0.025
Mine water 3 # in the south	8.53	<4	<10	0.06
Domestic sewage 3 # in the central	7.93	4	<10	0.22
Domestic sewage 1 # in the south	7.73	6	<10	4.37
Level 1 standard of GB8978-1996	6 - 9	70	100	15

1) There are 7 regions that are more severely affected by the geological environment (called Zone I), including the central industrial plaza, the Nanfengjing industrial plaza, the Dongfengjing industrial plaza, and the areas with subsidence depth greater than 1.5 m. These regions cover a total area of 1394.28 hm^2, accounting for 15.17% of the total research area, in which all industrial plazas are equal to 159.25 hm^2, accounting for 1.73% of the total research area.

2) There are 4 regions that are severely affected by the geological environment (called Zone II), including the areas with subsidence depth between 0.5 and 1.5 m. These regions are mainly distributed on the edge of Zone I, and cover a total area of 311.59 hm^2, accounting for 3.39% of the total research area.

3) There are 1 region that is lightly affected by the geological environment (called Zone III), including the areas with subsidence depth less than 0.5 and other areas without subsidence. This region cover a total area of 7482.42 hm^2, accounting for 81.44% of the total research area.

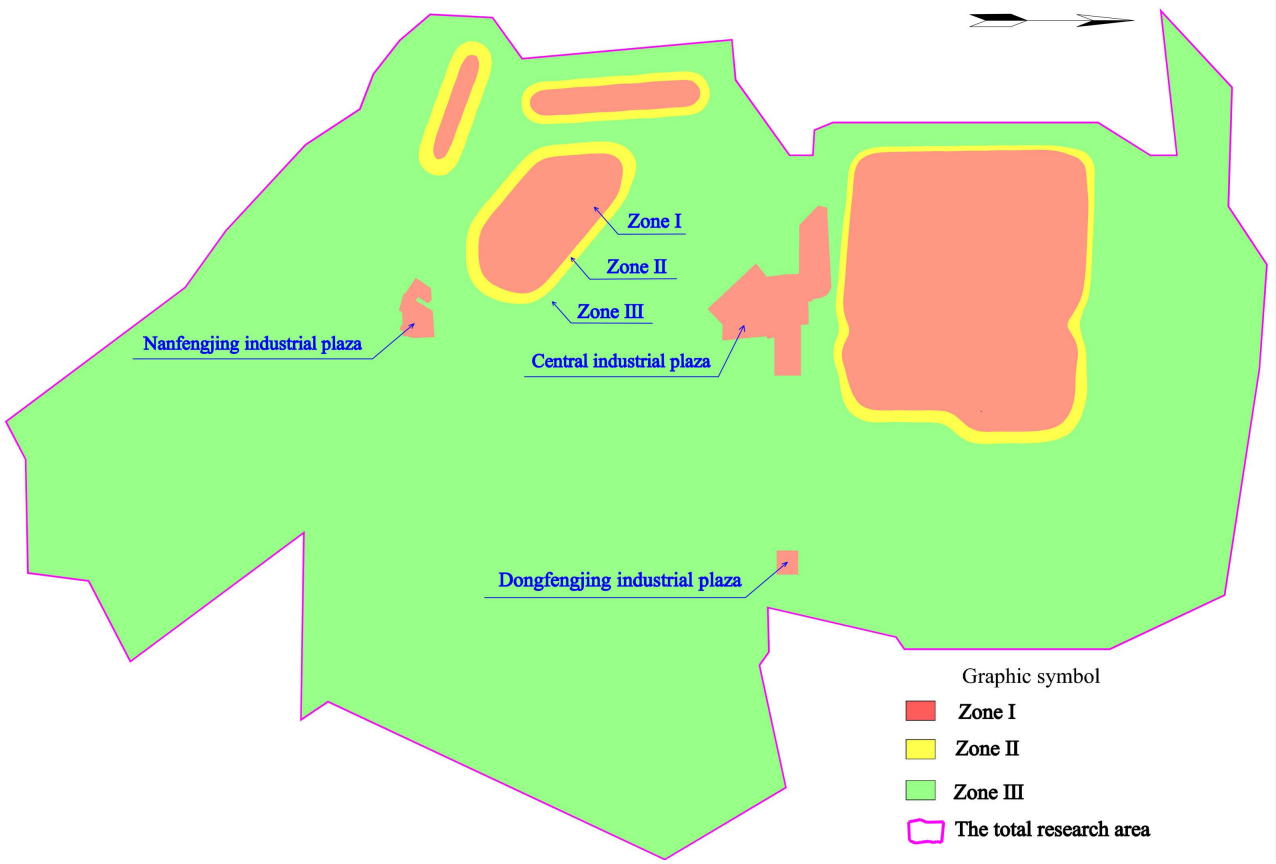

Figure 1. Partitions of the current mining geological environment in the Guqiao coalmine.

4. Assessment Results and Recommendations

To sum up, this section assesses the impact of coal mining on the geological environment and proposes some corresponding governance recommendations.

4.1. Results

The assessment results mainly includes four views as follows:

1) The geological disasters in the Guqiao coalmine is mainly subsidence. And the influenced regions cover an area of 2222.25 hm^2, in which the more severely influenced one is 1235.03 hm^2, the severely influenced one is 311.59 hm^2, and the lightly influenced one is 677.63 hm^2;

2) The terrain and landform destruction of the Guqiao coalmine is mainly caused by subsidence and occupation of industrial plazas. And the influenced regions cover an area of 2383.5 hm^2, in which the more severely influenced one is 1394.28 hm^2, the severely influenced one is 311.59 hm^2, and the lightly influenced one is 677.63 hm^2;

3) The production of the Guqiao coalmine has a slight impact on its water and soil environment;

4) It can be seen from the division of the Guqiao coalmine that Zone I mainly consists of the areas with subsidence depth greater than 1.5 m, Zone II mainly consists of the areas with subsidence depth between 0.5 and 1.5 m. Therefore,

geological environmental treatment should focus on the subsidence.

4.2. Recommendations

Connecting with the practice of environmental protection, some recommendations for treating the geological environment of the Guqiao coalmine can be provided as below.

1) According to the characteristics of multiple-seam mining, in the case of combining with the damage depth and stable settlement of all subsidence areas, comprehensive treatment of the geological environment should be carried out reasonably:

a) For stable settlement areas in which the subsidence depth is less than 1.5 m, the method called "dividing to level" is adopted to restore the original land use function, through measures such as cutting heights to fill depressions and supporting water conservancy facilities;

b) In the stable settlement areas in which the subsidence depth is greater than 1.5 m, the method called "digging deep to fill shallow" shall be adopted to form a pattern, including growing food at high places while breeding in low places, and constructing an ecological wetland park;

c) In areas affected by unsteady subsidence, methods such as afforestation and slope protections shall be adopted to improve the current status of the geological environment;

d) For the existing ground facilities such as industrial plazas, they may be restored after the coalmine is closed.

2) Enterprises shall carry out the geological environment monitoring by commission. When it is necessary, an eligible professional institution may be entrusted to dynamically capture related changes and make assessment, which can provide technical support for the treatment work.

3) Referring to the filling mining test within the nearby Xieqiao coalmine, appropriate filling tests can be carried out on the mining area, to reduce the range and degree of subsidence from the source.

5. Conclusion

Long-term coal mining will inevitably lead to many geological environment problems, which have a further impact on the local ecological and living environment. This article takes the Guqiao coalmine into account to assess the mining geological environment, and discovers that subsidence is the most serious problem and urgently needs to be addressed. The results provide a scientific basis for the geological environmental protection and restoration treatment of the Guqiao coalmine, and also give certain reference significance to other adjacent coalmines.

In the future work, we plan to research advanced technologies for the treatment of the mining geological environment. Especially under the concept of Industrial Internet, the reasonable application of Internet and big data technologies may be the new way, to achieve new goals of real-time monitoring, forecasting

and governance.

Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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