Design Strategy of Water Circulation System Above and Below Ground in Western Mining Area

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Abstract: Coal mines in ecologically fragile areas in western China are seriously deficient in water. The contradiction between coal mining and water shortage is extremely sharp. Therefore, how to effectively protect and utilize water resources has always been an important problem that plagues western mining areas. Based on the analysis of the water environment characteristics of the western mining area, a coal mine waters circulation system is designed. It consists of ground sponge facilities and groundwater reservoirs in the coal mine goafs.

1. Introduction

The western mining area is the main coal producing area of China. Water shortage is one of the bottlenecks restricting the sustainable development of the western mining area. In 2014, the National Development and Reform Commission issued the “National Key Basic Research Development Plan and Major Scientific Research Plan 2015 Project Application Guide” ([2015]. No. 52). It listed the “scale development of coal science and water resources protection in ecologically fragile areas in western China” as the key support direction. Therefore, the protection and utilization of coal mine water resources is one of the issues that China attaches great importance to.

The issue of water resources protection and utilization in ecologically fragile areas has always been one of the key topics of concern to scholars at home and abroad. In 1970 and before, related research topics focused on simple waterproofing[1-3]. From the late 1970s to the early 1980s, many academic research institutions and experts began to pay attention to the recycling of mine water[4-6]. Since the 21st century, more and more scholars have begun to study how to protect water resources while mining coal. Academician Qian Minggao proposed the concept of green mining for water conservation and coal mining[7-9]. Academician Gu Dazhao and his team studied and developed a technical approach of storage and utilization of mine water using underground reservoirs of coal mine[10], which included design, construction and operation technology[11]. They successfully built 32 underground reservoirs in the Shendong Mining Area, providing more than 95% of the water for the mining area[12].

Zhun Ge’er Coalfield, the research object of this subject, is located in the Loess Plateau. Due to the deep groundwater depth, agricultural areas in the loess plateau are mainly rain-fed agricultural areas[13]. Therefore, it is of great significance to study how to properly store and utilize rainwater in Zhun Ge’er Coalfield for ecological restoration work.

At present, the research on underground reservoir of coal mine is at the beginning and exploration stage in China, especially the research results of water circulation of coal mine based on sponge city concept are very few. There is still a dispute about whether it is necessary to build sponge city facilities and underground reservoirs in the ecologically fragile mining areas. However, further in-depth
discussions and researches should be carried out through typical pilot construction. Taking jungle coalfield as an example, this paper discusses the implementation strategies and control points of integrated construction of coal sponge facilities and underground reservoirs in semi-arid areas, so as to provide reference to other similar cases.

2. Overview of the study area

2.1 General climate characteristics
Zhun Ge’er Coalfield is located in Zhun Ge’er Banner, where the climate belongs to continental semi-dry climate. Its annual average precipitation is about 408 mm, and it decreases from southeast to northwest. Interannual and intraannual rainfall distribution is also very uneven. The annual rainfall in Zhun Ge’er Banner mostly concentrated in July, August and September, accounting for 60-70% of the annual rainfall. In addition, because of the high altitude, dry and windy climate, evaporation is 5 to 6 times of rainfall. Therefore, the storage and utilization rate of rainwater is very low[13].

2.2 Water and soil
The rainy season in Zhun Ge’er coalfield is characterized by frequent flash floods, short duration, large discharge and fast flow rate. Soil and water loss is serious in rainy season because of poor permeability of sandy soil. However, in the early stage of construction, the coal field has attached great importance to land reclamation and ecological reconstruction, and achieved remarkable results. For example, vegetation coverage increased significantly, forest land and artificial grassland area increased to 68%; soil erosion decreased by more than 85%; water evaporation decreased by about 17%-38%; soil conditions improved significantly, and permeability increased significantly[14].

2.3 Necessity of Building Sponge Facilities and Underground Reservoirs
In summary, water resources in ecologically fragile mining areas are seriously scarce and rainwater utilization rate is particularly low. Therefore, in order to maximize the protection of water resources, this study proposes a comprehensive strategy of making full use of rainwater and production water in mining areas (The section design intention is shown in Fig. 1.): combining the existing ecological infrastructure in mining areas, building an integrated project of sponge facilities and underground reservoirs, aiming to enhance the water cycle in mining areas, and recharge the water resources above and below the ground in mining areas.

![Figure 1. Diagram of Water Circulation System Above and Below Ground (From self-drawing)](image)
3. Design of water circulation system integrating ground up and down

3.1 Water circulation path
In the surface area, rainwater and floodwaters are pumped into the groundwater reservoir after they are transferred to the surface interception system through the surface collection and purification system. In the underground part, the mine water, the water in the mining area, and the rock formation water are simply purified and transferred to the underground reservoir[15, 16]. Its loop path is shown in Figure 2:

3.2 Regulation and storage systems
Free voids between broken and collapsed rock masses in goaf of coal mine are used to store and purify water resources. Its storage capacity is the total amount of free voids in the fractured rock mass within the water storage area of the goaf. On this basis, surface sponge facilities are used as auxiliary structures. During the rainy season and flood disasters, surface rainwater and other runoff are infiltrated, purified and collected, in order to replenish water in mining areas during the drought or emergency water use period.

3.3 Purification system
In the surface part, vegetation, green roof, purification pipe network, soil layer and other facilities are used to infiltrate, filter, precipitate and purify rainwater and flood. In the underground part, coal powder in goaf can react with pollutants in water to form chemical precipitates. And the clay minerals in gangue can adsorb cations in water. In addition, microorganisms in goaf can oxidize, decompose and adsorb organic substances in water body, so that water body in goaf can be purified[17].

4. Conclusion
As the main coal producing area in China, the sustainable development of water environment in western mining area has been hindering the ecological construction of mining area. Restoring water ecology, conserving water resources, improving water environment and improving water safety in mining areas have been the goals of green mine construction. Therefore, based on the concept of Sponge City, we propose an integrated water circulation system above and below ground, which consists of surface
sponge facilities and underground goaf reservoirs. We suggest that comprehensive measures such as seepage, stagnation, storage, purification, utilization and drainage should be taken to give full play to the purification and storage functions of surface vegetation, soil, microorganisms, coal gangue and microorganisms in goaf, so as to maximize the storage of rain and flood and reduce soil erosion. In addition, the production and domestic water in the mining area has also been well recycled.

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