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Abstract. China's mine water comprehensive utilization rate is low. The main reason for the increase in the utilization rate after 2015 is the reduction in coal production. The shutdown of a large number of coal mines by capacity has objectively led to a reduction in mine water volume. Based on the development and utilization of mine water, this paper clarifies the characteristics of mine water utilization mode, and discusses the classification of mine water utilization mode and suggestions for safeguard measures in terms of mine water utilization targets and treatment difficult. The research undertook in this paper will expand the utilization of mine water and improve the utilization rate of mine water. It will help enterprises realize the transformation of mine water into waste and realize the value-added effect of mine water. It is desirable for the unconventional water resources will be integrated into the water source. It can help ease the contradiction between water supply and demand in water shortage areas and improve the efficiency and utilization efficiency of regional water resources allocation.

1. Introduction

China is a big mineral resource country and a major mining country. It has discovered 172 kinds of minerals and 162 kinds of proven resource reserves. The National Development and Reform Commission and the State Department of Energy jointly issued the "Development Plan for Mine Water Utilization" point out that(National Development and Reform Commission,2013): In 2015, the mine water discharge of coal mines was about 7.1 billion m3, accounting for more than 80% of the total water discharge of various mines. The total annual industrial and civil water shortage in China is about 10 billion m3(Gu Dazhao, et al ,2016).Mine water is one of the available water sources. At present, the state's policy on mine water management requires recycling and prohibiting efflux. The 13th Five-Year Plan for Coal Industry Development (National Development and Reform Commission,2016)clearly states that in 2015, China's mine water utilization rate was 68%, and the utilization rate of mine water in 2020 increased to 80%.From the perspective of the supply side, there are more regional coal mines with more dissolved solids than 1000ml/L in the main coal producing areas of China, and the treatment and utilization costs are higher. Considering the demand side, relying on coal-based coal-fired power, coal chemical parks and other industrial clusters, the water quality and quantity of water are stepped and diversified, and the mine water is not fully utilized.

In 2017, China's coal mine water volume reached 5.35 billion tons, but the actual treatment and utilization is only 3.85 billion tons, the utilization rate is only 72%(He Xuwen,2018). The main reason

for the increase in the utilization rate is the reduction in coal production. The shutdown of a large number of coal mines by capacity has objectively led to a reduction in mine water volume.

In 2017, the "Notice on Printing and Implementing the "Implementation Measures for Expanding Water Resources Tax Reform Pilot" (Cai Shui [2017] No. 80) clarified that Beijing, Tianjin, Inner Mongolia, Ningxia, Shanxi and other nine provinces and municipalities are piloting the expansion of water resources tax reform. After the water resources tax is levied, it is clarified that the actual water consumption of the mine drainage is determined according to the displacement, and the tax collection and utilization of the mine water and the direct taxation of the direct discharge are specified. According to the requirements of water quality standards for discharge and utilization(Zhang Nan, et al.2019). The treatment and utilization of mine water can not only alleviate the contradiction between supply and demand of water resources in mining areas, but also avoid pollution to the water environment, generate economic benefits, reduce the tax pressure of enterprises, and promote the sustainable development of coal industry(Ni Shen hai, et al ,2019).

For areas that are not short of water, mine water is wastewater, but for water-deficient areas, mine water is a valuable resource. Based on the development and utilization of mine water, this paper clarifies the characteristics of mine water utilization model, and discusses the classification of mine water utilization mode by discussing mine water utilization object and treatment difficult. The research undertook in this paper will expand the utilization of mine water and improve the utilization rate of mine water. It will help enterprises realize the transformation of mine water into waste and realize the value-added effect of mine water. It is desirable for the unconventional water resources will be integrated into the water source. It can help ease the contradiction between water supply and demand in water shortage areas and improve the efficiency and utilization efficiency of regional water resources allocation.

2. Mine water treatment and utilization process

Domestic and foreign research and application of mine water treatment and utilization is relatively early(Lesley C. Batty, et al ,1992). Depending on statistics, the comprehensive utilization rate of mine water in the United States reached 81%. In overseas countries, coal mine water treatment is the focus of environmental protection work. The mine water produced in mining is regarded as a companion resource rather than a burden. The greater the amount of water in the mine, the more profit, the greater the economic benefit. After most countries have properly treated the mine water, some of the water are used in coal mine production water and domestic water in the mining area. Some of the water meet emission standards and are discharged into the surface water system(Xu Gaoqiang,2008; Nariyan et al ,2017).

Before the liberation, some coal mines in China began to pay attention to the utilization of mine water. The underground drainage in the mining area was directly used for coal washing, or after natural sedimentation and filtration, used for employees to be taken a bath. After liberation, uncontaminated roadway water or well-born water is used as drinking water in the mining area(Xia Daping,2008). As China's exchanges and cooperation with Japan, the United Kingdom and other countries increase. Coal mining technology and mine water treatment technology have improved(Zhang Shuanliang,2016; Zhu Youbin, et al,2016). In recent years, with the increasing problem of water resources, national environmental awareness and awareness of comprehensive utilization of water resources. The work of mines in China on the treatment of mine water, especially in the deep treatment of mine water, has been gradually carried out. Ecological protection workers are also actively studying the effective ways of mine water treatment and rational utilization. At present, the domestic use of mine water is mainly divided into the following situations:

(1) Mine water is directly used without treatment. In this case, the mine water does not contain toxic elements, or contains a small amount, but does not exceed the efflux standard.

(2) The mine water is subjected to conventional coagulation, sedimentation and filtration treatment, and is then treated for industrial, landscape, aquaculture or efflux. In this case, the mine water does not contain toxic and harmful elements. The pH value is close to neutral, and the salt content is not high.

(3) The mine water is used in industry or drinking water after advanced treatment. This situation refers to the treatment of acidic water mine water

(4) Comprehensive utilization of high salinity mine water. At present, only a few industrial water can directly use high salinity water. In most cases, the conventional removal of contaminants other than salt is performed, and then desalinization treatment is carried out after entering the desalination equipment. Due to the high cost and high operating cost of desalination equipment, the desalination process has been applied in the northwestern region where water resources are rare.

3. Characteristics of mine water development and utilization mode

Any model is just an optimized structure established under artificial design and control. It is constituted by interactions between human and material conditions, economic and technical conditions, and has the characteristics of being controlled and regulated. The development and utilization mode of mine water has the characteristics of diversity, complexity, coordination and safety.

3.1. Diversity

The mine water meets the standard discharge and returns to the river and lake mode; after reaching the standard, it is applied to the nearby utilization mode of non-industrial water such as surrounding agricultural irrigation, landscape greening, aquaculture, and drinking. Industrial park utilization model applied to surrounding industrial enterprises after reaching the standard. Returning to the river and lake model, increasing river flow, it has ecological benefits; the nearby utilization mode and the industrial park utilization mode, recycling mine water resources as secondary resources, and transforming them into valuable products with economic and social benefits.

The use of mine water has alleviated the contradiction of water shortage in the northern region to a certain extent, and achieved the unification of economic, ecological and social benefits. According to the mine water quantity, water quality characteristics and the needs of surrounding water users, there are many characteristics such as the coexistence of multiple utilization modes, one mine, one pool and one park.

3.2. Complexity

Affected by many factors such as hydrogeological conditions and mining years, the mine water quantity has the characteristics of dynamic changes. ① At the beginning of mining, there are relatively many aquifers penetrating, each aquifer is in a natural saturated state, and the water content is strong. As the mining area increases, the roof falls and is connected with the water-conducting fracture zone. Groundwater in the mine directly penetrates into the pit, and the amount of water in the mine is gradually increasing.②. In the middle stage of mining, with the extension of mining time, the water level of the aquifer is continuously reduced, the mine water is changed from pressure bearing to no pressure, and the mine water quantity can only be replenished by the infiltration quantity, which is in the state of recharge and runoff balance. ③. In the later stage of mining, the water in the aquifer is partially drained, the water-conducting fissure zone is slowly filled, the recharge of groundwater in the groundwater is gradually reduced, and the amount of water in the mine is gradually attenuated. ④ At the end of the mining period, the mine drainage almost stopped, but due to the existence of the aquifuge, the goaf gradually accumulated water and evolved into a “groundwater reservoir”.

During the coal mining process, the coal seam roof is disturbed to form the “upper three belts”, so that the groundwater in the coal seam overlying aquifer directly or indirectly seeps into the mine. The mine water is in full contact with the surrounding rock mass during the infiltration process. Under the action of chemical and physical, the water-rock reaction accelerates, the calcium and magnesium ions in the rock dissolve in water, and the total hardness and total salinity increase, which changes the water. Chemical properties that increase the hardness and salinity of mine water. In addition, the harmful elements contained in coal will dissolve in the water when the coal is in contact with the mine water, changing the water quality of the mine water, and the discharge of the mine water will increase the pollution of the groundwater. Under the influence of hydrogeology and other conditions, the mine water is dense according to the source of recharge (porous water, fissure water, karst water). The main

components include suspended solids, high salinity, heavy metal, high fluorine, acidity and alkali. The concentration of radioactive pollutants, etc.), the concentration also changes.

The development and utilization mode of mine water is characterized by complexity in water quantity and water quality.

3.3. Coordination

Coordination refers to the multiple associations between subsystems and components in the system, such as cooperation, complementarity, and synchronization, and the coordination structure and state that the system presents due to these associations. In the interaction process between subsystems and components and systems in the system and the external environment, there are always various contradictions and various inconsistencies. Only by constantly adjusting, can we maintain a balanced and harmonious relationship between systems, thus making the system The whole system and each subsystem can fully exert its functions and achieve the overall optimal effect of the system.

The coordination of mine water utilization is mainly reflected in two aspects: one is the supply and demand sides, that is, the water supply side of the mine water and the water users; the second is the coordination condition, that is, the water quantity and water quality conditions to be met by both the supply and demand sides.

3.4. Safety

Security refers to the ability of a subject to maintain its own safe state under the influence of the external environment.

The safety of mine water development and utilization mode is reflected in the following three aspects: First, safeguarding safety, as a water source, ensuring water demand for water users; The second is the standard constraint, which meets the water quality requirements of different water users in different departments; The third is the restrictive factor, that is, the development and utilization of mine water is safely combined with the requirements of national and local policy documents, mining area planning, “three red lines”, “double control”, and water function zones.

4. Classification of mine water development and utilization mode

4.1. Use object classification

Considering the requirements of two-way coordination between supply and demand, it is proposed that the mine water is used nearby, facing the industrial chain of the park, and returning to the safe utilization mode of rivers and lakes:

Near-use mode: The water quality of the collected and treated mine water meets the requirements of the plant water use, and the nearby use mode of the plant itself (Figure 1).

For the industrial chain utilization mode of the park: the water quality of the collected and treated mine water meets the needs of water users, and is adjusted and transferred to the industrial park enterprises, surrounding agricultural irrigation, landscape greening, aquaculture, life and other non-industrial industries. The mode of utilization of water users (Figure 2).

Return to river and lake utilization mode: When there is no water object around the mining area, the collected and treated mine water will reach the standard discharge, increase the river ecological base flow, supplement the river and lake flow, and return to the river and lake utilization mode (Figure 3).

Figure 1. Near use mode

Figure 2. Industrial chain for industrial parks

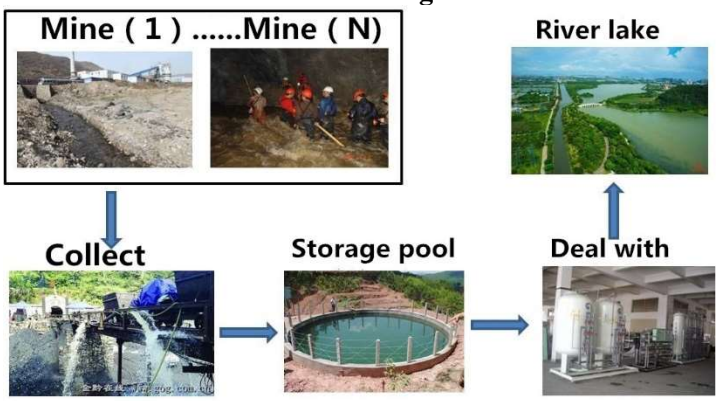

Figure 3. Return to river and lake utilization mode

4.2. Sort by processing difficulty

Considering the water quality category of mine water, the simple processing utilization mode, the deep processing utilization mode, and the special processing utilization mode are proposed:

Simple treatment and utilization mode: clean mine water, suspended solids water through coagulation and sedimentation, pre-oxidation, filtration, disinfection process for secondary treatment to meet the production and domestic water requirements.

Advanced treatment utilization mode: high-mineralized mine water (also known as salt water, brackish water), acid mine water through salt elimination, filtration reverse osmosis and other processes after the production and domestic water requirements.

Special treatment and utilization mode: The utilization mode of the production and domestic water requirements for the treatment of mine water containing harmful and toxic elements by concentration and separation.

4.3. Mine water development and utilization mode refinement classification

In summary, considering the difficulty of the mine water quality treatment process, considering the mine water utilization target, the classification mine water utilization mode is refined based on the relationship between coal supply and demand (Table 1).

Table 1. Classification of mine water utilization patterns

Mode		Self-use	Industrial water	Non-Industrial water	No efflux	Discharge	Recycling after non-standard discharge	Mine water treatment difficulty	Remarks
Near use	1	√			√			the simple processing, the deep processing,	Mine water availability < Self-use of water

								the special processing	
	2	√				√		the simple processing, the deep processing, the special processing	Self-use of water < Mine water availability（No water needs outside the plant）
Facing the park industry chain	1	√	√		√			the simple processing, the deep processing, the special processing	Self-use of water < Mine water availability < Self-use of water + Industrial water consumption outside the plant
	2	√	√	√	√		√	the simple processing, the deep processing, the special processing	Self-use of water < Mine water availability < Self-use of water + Non-industrial water consumption outside the plant（No industrial water demand outside the plant）
	3	√	√			√		the simple processing, the deep processing, the special processing	Self-use of water + Industrial water consumption outside the plant（No industrial water demand outside the plant）< Mine water availability
	4	√	√	√	√			the simple processing, the deep processing, the special processing	Self-use of water + Industrial water consumption outside the plant < Mine water availability < Self-use of water + Industrial water consumption outside the plant + Non-industrial water consumption outside the plant

	5	√	√	√		√		the simple processing, the deep processing, the special processing	Self-use of water + Industrial water consumption outside the plant + Non-industrial water consumption outside the plant < Mine water availability
Return to the river	1	√				√		the simple processing, the deep processing, the special processing	Self-use of water < Mine water availability（No need for water for industrial and non-outdoor industries outside the factory）
	2	√					√	the simple processing, the deep processing, the special processing	Self-use of water < Mine water availability（Centralized treatment and utilization, water demand for industrial off-site）

5. Conclusions and recommendations

5.1. Conclusion

1.The development and utilization of mine water is characterized by diversity, complexity, coordination and safety.

2.Development and utilization of mine water Considering the two-way coordination requirements of supply and demand, it is divided into the nearest utilization, facing the industrial chain of the park, and returning to the safe utilization mode of rivers and lakes; considering the mine water quality category, it proposes a simple treatment utilization mode, a deep processing utilization mode, and a special treatment utilization mode.

5.2. Recommendations

Administration: The state has requested that unconventional water sources be included in the unified allocation of water resources, and the proportion of unconventional water source utilization to total water is also used as an assessment indicator in the most stringent water resources management assessment. However, there is still no corresponding national level approach or regulation in the system construction of unconventional water use. Recommendations: First, based on the "13th Five-Year Plan for Water Conservancy Reform and Development" and the "Water Pollution Prevention Action Plan", based on the "Water Law", "Water Pollution Prevention Law" and "Environmental Protection Law" and other laws and regulations, the mine water resources are formulated. Using the management method and the legal and regulatory system, the mine water utilization work is incorporated into the legalized track. It is the responsibility and obligation of the enterprise to establish the status and function of the important water resources in the mine by legally establishing the mine water resources utilization. Establish the

mine water utilization production project management. Measures, product quality supervision and management system, so that the mine water utilization work is standardized and rapid development; Second, the competent national authorities should strengthen leadership and coordination. All regions, relevant departments, enterprises and institutions should strengthen their leadership over the use of mine water, determine the responsibility of specialized agencies and special personnel, and be responsible at all levels and implement them step by step. Give full play to the role of intermediaries such as industry associations, establish a mine water technology exchange service platform, strengthen technical guidance and services, assist project management and inspection, technical guidance and training, timely understand the problems, establish information bases, strengthen information collection and Exchange, serve the competent government departments and enterprises, and promote the rapid development of mine water utilization. The third is to study and formulate industrial policies, fiscal and taxation policies and other related support policies to promote the use of mine water, and require areas or enterprises with mine water, especially high-power enterprises such as electric power and chemical industry. The production and use of new or expanded projects should be given priority. Mine water; tax incentives for related companies that develop and utilize mine water.

Economics: At this stage, the water resource fee is moving toward the water resource tax reform. The original problem when collecting water resource fee for mine water is that if the direct discharge is not charged, the water resource fee will not be charged, but the treated mine water needs to collect water when it is reused. Resource fees have caused a lot of mine water to get wasted.Recommendations: First, encourage the use of mine water through other means such as “rewarding with awards” or reducing corporate taxes. The mine water resources utilization work is mainly based on enterprises. The state should give preferential policy loan support, include the key content of water-saving projects, and make unified arrangements for priority projects; Second, large enterprises drive small enterprises to develop together. With reference to the water rights trading center model, a mine water safe and efficient utilization center is set up. Large enterprises take the lead in collecting surplus mine water from surrounding small enterprises. According to water quality and water quantity, large enterprises independently set water prices. The benefits generated by the surrounding production and domestic water are distributed by large enterprises.

Technology: According to different scales and water quality, select the processing technology and technical route according to local conditions, effectively strengthen the pace of technology research and development, demonstration and industrialization, promote the development of mine water utilization industry, adhere to the combination of independent innovation and production, learning and research, and accelerate Use process technology and equipment research and development.

Supervision and management: First, in the management, the sound and perfect system should be combined with the requirements of modern process organization management. Second, at the decision-making level, the operational assessment of the mine water safe and efficient utilization system is included in the comprehensive assessment level of the mine, and the laws and requirements are strictly followed in accordance with the model, and the power is promoted and continuously improved to ensure the safe and efficient use of the mine water. Strengthen professionalism of middle and senior management personnel, improve the efficiency of information exchange among management personnel, and take corresponding measures according to the emergency plan for the first time in the event of an accident.

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References

[1] National Development and Reform Commission .Development plan of mine water utilization[S]. [2013]118,2013.
[2] Gu Dazhao,Zhang Yong,Cao Zhiguo.Technical progress of water resource protection and utilization by coal mining in China[J]. Coal Science and Technology. 2016,44(1):1-7.
[3] National Development and Reform Commission, National Energy Board. The 13th Five-Year Plan for the Development of Coal Industry 2016.12.
[4] He Xuwen. It is necessary to increase the utilization rate of mine water to achieve zero emissions. [EB/OL].http://www.membranes.com.cn/xingyedongtai/gongyexinwen/2018-09-27/34280.html.2018-09-27.
[5] Zhang Nan,He Hongmou Li Shu,Li Lin,Du Kai,Li Zhaoyue.Preliminary study on water quality index of mine drainage in China.China water resources[J]. 2019.03:4-7.
[6] Ni Shen hai,Peng Yuejin,Zhang Nan, et al.Study on industrial chain mode of coal mine water utilization to industrial zone[J]. China Energy and Environmental Protection.2019(41)3:113-116.
[7] Lesley C. Batty, Paul I.Younger. 1992.The Use of Waste Materials in the Passive Remediation of Mine Water Polution [J]. Surveys in Geophysics, 25(l):55-67.
[8] Xu Gaoqiang.2008. Research on prediction model of mine water inflow in coal mine area of Shanxi Province [D].Shan Xi taiyuan: Taiyuan University of Technology.
[9] Nariyan E，Sillanp M，Wolkersdorfer C. Electrocoagulation treat-ment of mine water from the deepest working European metalmine-performance， isotherm and kinetic studies[J]. Separation and Purification Technology,2017,177(4),363-373.
[10] Xia Daping.2008. Research on mine water resources in Jiaozuo mining area [D].HeNan province Jiaozuo: Henan Polytechnic University.
[11] Zhang Shuanliang. Study on sustainable use and processing tech-nology of mine water resources [J]. China Science and Technology Panorama Magazine,2016(17):170.
[12] Zhu Youbin,Zhu Lin,Liu Wengang,et al. Research and practice of mine water cyclic utilization[J].Zhongzhou Coal,2016(11):151-155.