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Cause analysis and treatment of acid wastewater pollution in xiayuanqiaotou coal mine of Kaili City, Guizhou Province

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ABSTRACT

In this paper, the acid wastewater pollution caused by the closed pit of xiayuanqiaotou Coal Mine is taken as an example. Through hydrogeological survey and field inspection, the geological and hydrogeological conditions of the study area are understood, and the cause and discharge of acid wastewater pollution in the mining area are analyzed. The results show that the goaf and coal gangue leaching water formed by the disorderly mining of small coal kilns in the Yudonghe Vally are the main sources of acidic wastewater pollution, and direct drainage from the mine mouth is the main drainage method of pollution in the Yudong Vally.Based on this, the technology of source control plus terminal treatment has been adopted, and applying regional water treatment and prevention technology to treatment is a new model of both specimens and treatments.which will play a significant role in the treatment of acid mine water in Guizhou and the south in the future.

Keywords: Acid wastewater pollution; Coal mine; Treatment

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1. Introduction

Affected by factors such as coal resource depletion, resource integration and elimination of backward production capacity, a large number of coal mines in China have been or are on the verge of closure [1]. According to the prediction of key consulting projects of Chinese Academy of engineering, the number of coal mines to be closed in China will reach 15000 by 2030 [2]. With the closure of coal mines, groundwater pollution has become a major problem to be solved. After the closure of the coal mine, the pumping and drainage of underground water will stop, and the underground water will rebound into the goaf. There are many harmful substances in the goaf, such as pyrite, which is easy to cause the content of iron, manganese and sulfuric acid in the underground water to exceed the standard. Untreated mine water is directly discharged to the surface, which will have a serious impact on the surrounding soil, aquatic organisms, nearby water bodies and residential water.

Xiayuanqiaotou mine is located in the Yudonghe Vally of Kaili City, Guizhou Province. Since the 1990s, township enterprises have been vigorously developed. Coal mining activities have been carried out on both sides of Yudonghe in Kaili City, mainly in the form of small coal mines. Around 2006, in order to improve the mining environment and ensure the production safety of coal mines, small coal mines in Kaili City were closed one after another. However, for many years, the disordered mining of small coal mines, the mine wastewater directly discharged into Yudong river without treatment, It leads to the problem of acid wastewater pollution in Yudong River Basin. The pollution control of yudonghe coal mine wastewater is a strong requirement of Kaili city's social and economic sustainable development, and also the goal of water environment comprehensive treatment.

Xiayuan Qiaotou Coal Mine Acid Wastewater Treatment Project is the first pilot sub-project of the comprehensive environmental management project of the Yudonghe Vally in Kaili City. The author analyzes the geological and hydrogeological conditions of the Qiaotou coal mine in Lower Courtyard, the causes of acid wastewater pollution and the pollution discharge situation, to provide a basis for the pollution treatment of acid wastewater, and then propose a pollution control plan.

2. Geological profile of the study area

2.1 Geological characteristics

The study area is located in Xiayuan Village and Laoshan Village, Longchang Town, Kaili City. The regional terrain is mainly low mountain erosion-dissolution landform. The highest elevation can reach 973m, the lowest elevation is 807m, and the relative elevation difference is 166m. The general terrain is high in the north east and low in the south west. The annual average temperature is 15.7℃ and the average precipitation is 1244mm. The study area is densely forested, with a vegetation coverage rate of 53.28%.

The exposed strata in the study area range from old to new: Upper Silurian Wengxiang Group ($S_{2-3}wn$); Devonian Yaosuo Formation (D_3y); Lower Carboniferous Baizuo Formation (C_1b); Lower Permian Liangshan Formation (P_2l), Qixia Formation (P_{2q}), Maokou Formation (P_2m); Cenozoic Quaternary (Q). Among them, the coal-bearing strata are mainly the Lower Permian Liangshan Formation, and the lithology is composed of quartz sandstone, carbonaceous shale, coal seams, bauxite clay, and pyrite clumps or nodules in some areas. The group is roughly divided into three sections, with a total thickness of 20-30m.

2.2 Hydrogeological characteristics

According to the occurrence conditions, hydraulic characteristics, hydraulic properties and geological structure of groundwater, the study area mainly includes four layers of aquifers, namely the Cenozoic Quaternary sandy gravel pore aquifer, Permian Maokou Formation-Qixia Formation clastic ash Karst fissure aquifer, lower Carboniferous Baizuo formation dolomite karst fissure aquifer, Devonian upper Yaosuo formation bioclastic limestone karst fissure aquifer.

Carbonates are widely distributed in the study area. The surface karst forms are dominated by stone teeth, karst trenches (troughs), depressions, and karst caves, and underground are dominated by sinkholes, karst caves, karst pipes and pores. The area is mainly supplied by atmospheric precipitation. The supply, runoff, and drainage of karst groundwater are affected by topographical cutting, lithology and structure. Karst groundwater flows in the form of crevices, pores, caves, pipelines and underground rivers.

Xiayuan Qiaotou Coal Mine is located in the middle section of Pinglu River, a tributary of Yudonghe, and is an important tributary of the right bank of Chong'an River. The direction of the Yudong River in the northwestern part of the hydrogeological unit of Xiayuan Qiaotou Coal Mine is the drainage boundary, and the other directions are the replenishment boundary, with an area of 4.35km2. In the area, atmospheric precipitation infiltrates to replenish the Qixia and Maokou formations and then replenish mine water in the goaf, producing acidic water. It is concentratedly discharged in the local river valley in the form of karst springs or mine shafts.

3. Analysis of the cause and discharge of acid wastewater in Qiaotou coal mine

3.1 Causes of acid wastewater in Qiaotou coal mine

In the early 1980s, the large-scale mining of coal resources in the Yudong Riverhe Vally was mainly in the form of small coal kilns. Private digging and chaotic mining were serious, resulting in intricate underground coal roadways and the formation of large-scale gobs, which resulted in the formation of coal-bearing strata and upper mining areas. The carbonate rocks are connected to each other, and the upper karst water enters the pit, and physically and chemically reacts with coal seams and coal gangue, and produces mine wastewater rich in iron and manganese ions in the water body. Most of the local mine shafts are arranged on both sides of the river. After the groundwater is polluted, it is drained along the well head and eventually flows into the river, causing pollution in the Yudong Riverhe Vally. On the other hand, the random stacking of coal gangue. Harmful components are precipitated by rainfall leaching and pollute surface water, groundwater and soil. Yudonghe is seriously polluted by acid wastewater (Fig.1). Yudonghe and its upstream Baishui River, tributary Pinglu River-Dashan River are mostly brownish yellow, rusty yellow, reddish brown, with high turbidity, granular yellow or red Brown suspended matter, smooth to the touch, with iron smell; the current water body of the Yudonghe Vally is inferior to Grade V [3].

a. Reddish brown fish hole river water b. Red-brown dams and riverbeds soaked by river water

Fig.1 Red-brown river water, riverbed and structures

3.2 Discharge of acidic wastewater

Xiayuan Qiaotou Coal Mine has been mined by private coal mines since the 1990s, with a mining scale of 30,000 tons/year. It uses inclined shafts and flat tunnels to develop coal. The long-wall retreat type full caving method is used for mining. Because the coal seam is thin, manual mining is adopted. Combined transportation of labor and machinery. According to the survey, the mining area of Qiaotou Coal Mine in Lower Courtyard is mainly in the northwest and east, with a mining elevation of 825~750m and a mined area of about 0.3 km^2. There are 4 shafts, namely the main shaft and the main air shaft, which are not completely closed. The auxiliary shaft and auxiliary air shaft are permanently closed. Xiayuan Qiaotou Coal Mine currently has two water outlets, namely the Qiaotou Coal Mine’s main shaft and the main air shaft, which are located about 30m away on the east bank of Pingluhe Village.

In July-August 2017 and November-December 2017, methods such as data collection, field measurement, sampling and testing were used in the treatment area to investigate the acid wastewater and water pollution of the Qiaotou Coal Mine in the Lower Courtyard.

According to the survey, Qiaotou Coal Mine is directly discharged by gravity at the mouth of the mine (inclined shaft, flat tunnel, air shaft, drainage lane, etc.), which is the main drainage method of pollution in the Yudonghe Vally. This type of drainage method is greatly affected by rainfall, and changes significantly with the seasonality. The water volume in the wet season increases significantly, and the water volume in the dry season gradually decreases. When atmospheric precipitation infiltrates into the goaf and gathers and the water level is higher than the wellbore, groundwater flows out along the wellbore. Because of its large cross-section, smooth flow and large discharge, it becomes the main channel for mine water drainage. The two main and auxiliary shafts are located on the slope of the river bank, and there are two water outlets. In July-August 2017 and November-December 2017, two water outlets were surveyed on the discharge of acidic wastewater (Tab.1). The discharge flow of wastewater during the dry season is 10~20m^3/h, and during the heavy rainfall period, it can reach nearly 100m^3/h.

Tab.1 Statistics of acidic water discharge in the study area

Wellhead	Survey date	Flow rate (m^3/h)
	2007.07.12 (wet)	120
Main shaft	2007.12.10 (dry）	12
(Elevation +685.00m)	2008.03.15(normal)	35
Wind shaft	2008.06.18 (wet)	118
(Elevation +694.00m)	2008.11.06 (dry）	10

3.3 Water pollution

From July 2017 to December 2018, samples of coal mine wastewater were taken from the main shaft head for water quality testing (Tab. 2). The test items are: pH, total iron, total manganese, and sulfate. The wellhead water output is about

10m^3/h~120 m^3/h, the color is brownish yellow, the pH is 3.40~5.65, the total iron content is 224.79~388.12 mg/L, and the total manganese content is 58~85 mg/L, far exceeding the coal industry Pollutant discharge standards.

Tab. 2 The polluted water quality test table in the study area

Wellhead		Sulfate (mg/L)	Iron (mg/L)	Manganese (mg/L)	PH value	colour
Main shaft	2017.7.12	316	44.79	6.9	5.65	Brownish yellow
	2017.10.12	340	88.12	12.5	3.40	Brownish yellow
	2018.3.15	351	78.90	7.5	3.44	Brownish yellow
Wind shaft	2018.6.18	302	38.52	5.8	5.12	Brownish yellow
	2018.11.6	366	80.73	11.8	3.49	Brownish yellow

On the whole, most of the mine water in the treatment area is acidic. The water quality factor is reflected in the excessive pH value of the mine water and the number of sulfate coal mines accounted for 75% and 85% of the total coal mines investigated. The pollution contribution ratio reached about 30%; in the field survey, in the polluted coal mine water, the bottom mud or rock soil at the bottom of the drainage was reddish brown, which was caused by the precipitation of iron and its compounds in the water body, which was reflected in the coal mine from the water quality factor. The total iron exceeding the standard in the well water accounts for 80% of the total surveyed coal mines and contributes to the overall pollution of the mine water.

The treatment area is a typical karst landform area. Karst caves, underground rivers, and corrosion pipelines are extremely developed. Acid wastewater from coal mines can easily communicate with uncontaminated aquifers through karst channels and faults, causing tandem pollution of water bodies in other aquifers and causing local residents. The production and life have a great impact, seriously affecting the surface water environment in the basin.

4. Research on Water Pollution Treatment Plan of Qiaotou Coal Mine

4.1 Current status and development trend of coal mine acid wastewater treatment technology

(1) Transform from low-efficiency and high-cost processing methods to high-efficiency and low-cost processing

The current acid wastewater treatment technology methods mainly include chemical, physical and biological treatment, such as neutralization method, microbial method and constructed wetland method [4]. The neutralization method uses the acid and alkali in the chemical process to react, and the neutralizer is put into the acidic wastewater to improve the pH of the wastewater. The neutralization method can effectively neutralize the acidity of wastewater and remove a large amount of metal ions in the water. However, they have serious sludge scaling, easy to block pipelines and deposits with a large amount of sludge, and are prone to secondary pollution. At the same time, the purchase of neutralizers is expensive and requires regular management and maintenance [5]. The main principle of constructed wetland is to use the combined effect of various physical, chemical and microbial triple comprehensive effects in the urban natural ecological management system and the environmental role of the constructed wetland to play a role, through the sewage filtration of various soil pollutants, Various methods such as adsorption, deposition, ion exchange, plant fungus absorption, and inhibition of the comprehensive decomposition of bacteria and other microorganisms are used to achieve high efficiency and purification of soil and sewage [6]. However, the construction site is controlled by topographical conditions. The biological method uses microorganisms-Thiobacillus ferrooxidans to continuously oxidize ferrous iron under the acidic conditions of sufficient oxygen supply, so that it releases a large amount of oxidizing energy and effectively removes the iron agent contained in the mine water, and then puts in lime Milk is neutralized, and then precipitation and filtration are performed to clean the water quality [7]. The microbiological method is still under research and has not been used on a large scale. How to avoid the drawbacks of the above processing methods, reduce processing costs, and improve processing efficiency.Many scientific research workers have carried out a lot of work, such as putting forward the sewage subsection and multistage treatment, etc. the sewage treatment technology has changed from the low efficiency and high cost treatment method to the high efficiency and low cost treatment method, which has become a trend of acid wastewater treatment.

(2) Transformation from terminal treatment to source control

For mine wastewater treatment, source control is more meaningful than terminal treatment. Source control treatment methods include the control of the source, such as the treatment of coal gangue to reduce the discharge of pollutants. Use coal gangue to generate electricity, paving roads, making bricks and filling goafs, etc. It can not only achieve the utilization of coal gangue, but also reduce the emission of pollution sources [8]. To block the contaminated channel, use methods such as curtain grouting, isolation and blocking to seal the source of contamination and block the contaminated channel. In the process of closing the mine, the excavation of abandoned roadways, shafts and bad boreholes are filled and sealed, and the potentially dangerous water areas are sealed or isolated by curtain grouting. Carry out anti-seepage treatment on the bottom soil or vadose zone such as gangue piles and collapse pits to prevent leaching and infiltration. At present, the new source control technologies mainly include suppression of iron oxidizing bacteria, passivation treatment, engineering coverage, and filling technology.

(3) Development from standard processing to resource-based processing

At present, the treatment of acidic wastewater is directly discharged after reaching the standard, and the reuse rate of the treated wastewater is low, which is a waste of resources. After treatment of mine water resources, it can be used for coal washing water, cooling water, agricultural irrigation and urban greening [9].

4.2 Selection of governance technology for source control plus terminal treatment

Analyze the causes of mine water pollution, combine the conditions of coal mine wastewater discharge, and choose to implement source control plus terminal solutions. Use key channel blocking, vertical curtain grouting (vertical area treatment), goaf filling and other treatment techniques to block the passage of groundwater into the mine, so as to reduce the total discharge of acidic wastewater from the source; at the same time, Adopt the end treatment of permeable reaction wall-continuous alkali -constructed wetland, and finally realize the discharge of acidic wastewater up to the standard.

Regional treatment technology is to use multi-branch horizontal directional drilling technology to grouting and transform the roof water-bearing (impervious) layer of the goaf within the treatment range through ground construction drilling to achieve the comprehensive hydraulic connection between the roof aquifer and the goaf. Technical method. That is, based on the exploration of the height of the development of the water-conducting fissure zone in the roof of the coal seam, the use of bedding horizontal wells and sidetracking branch horizontal well drilling methods combined with high-efficiency ground high-pressure grouting control technology is used to detect the water-conducting channels and primary dissolutions, Structural fissures and other grouting transformation [10].

Permeable reaction wall technology is to fill the wall with a suitable reaction medium, and then set the wall at a position perpendicular to the flow direction of the contaminated groundwater. When the local water flows through the reaction wall, the pollutant components will interact with the reactants in the wall. Physical chemistry or Biological reaction, so as to achieve the purpose of removing pollutants [11-12]. Permeable reactive wall (PRB) technology+bioremediation technology can be used, that is, the corresponding active materials (such as organic solid mixture, limestone or gravel, etc.) are filled in the wall, and the pollutants and active materials in the water will be precipitated, adsorbed, oxidized and reduced. Biodegradation and other reactions, together with the alkalinity generated by the dissolution of limestone, act on the wastewater to transform the pollutants in the water into an environmentally acceptable form. At the same time, reducing microorganisms grow in the permeable reaction wall and produce alkalinity. Together with the alkalinity generated by the dissolution of limestone, it acts on wastewater, and metal ions are removed in the form of sulfide, hydroxide, and carbonate precipitation [13]. It does not occupy floor space and is relatively economical and convenient. However, the wall filling materials need to be replaced regularly.

The continuous alkali reaction technology device is composed of water layer, organic matter layer and alkalinity layer from top to bottom. Wastewater flows in from the top of the pool and passes through the organic layer. The treatment of acidic wastewater in the organic layer is mainly to use sulfate-reducing bacteria (SRB) in this layer to convert sulfate into sulfide or elemental sulfur and finally remove it. Then flow into the lower alkalinity layer. The uppermost water layer prevents the organic layer from contacting air, reduces oxygen diffusion, and can also adjust the temperature, which can reduce the oxygen concentration and promote the system to produce more alkalinity. The lowest alkalinity layer is composed of limestone or other alkali-generating inorganic substances, which can directly increase alkalinity and precipitate metal ions [14-15].

5. Conclusion

1) Xiayuan Qiaotou Coal Mine is located in the Yudonghe Vally. Small coal mines have serious disorderly mining, forming intricate underground coal roads and goafs, causing the coal-bearing strata to be connected to the overlying carbonate rock, and karst water enters the pit and connects with the coal seams and coal gangue produce physical and chemical reactions, producing mine wastewater rich in iron and man-

ganese ions in the water body. Coal gangue leaching is another cause of acid wastewater pollution.

2) Qiaotou coal mine head (inclined shaft, flat tunnel, air shaft, drainage lane, etc.) drainage is the main drainage method of pollution in the Yudonghe valley, which is greatly affected by rainfall. The water quality test of the coal mine wastewater samples at the main shaft head showed that the pH value, total iron, total manganese, and sulfate test values far exceeded the coal industry pollutant discharge standards.

3) Analyze the current situation and development trend of acid wastewater treatment, and adopt the treatment plan of source control plus terminal treatment**.** This model applies regional water treatment and prevention technology to the treatment of acid mine water in mining areas. It is a new model that treats both symptoms and root causes. The successful application of this model will provide a certain demonstration and reference for the future management of mine water in Guizhou and the South.

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