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The Technology for Underground Treatment of Coal Mine Drainage Used as Process Water: a Case Study of Jining No.3 Colliery

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Abstract According to the water quality characteristics of mine drainage of Jining No.3 colliery, the water treatment process combined goafs, an aeration oxidation tank with interacted washing filters is used to purify mine drainage underground as sprinkling water for dustproof and cooling water for devices, without dosing any coagulants. The purified mine drainage is re-treated further by reverse osmosis (RO) process as preparing water for emulsion in fully mechanized mining faces, without boosting pressure by using the pressure existed in the water supply network. The operating practices show that: under the conditions of purified treatment scale of 200 m^3/h, advanced treatment scale of 6m^3/h, the average mass concentration of suspended solids(SS)of 210 mg/L, total dissolved solids (TDS) of 2279 mg/L, SO_4^{2-} of 1012 mg/L and total hardness of 204 mg/L in the influent, the average concentration of turbidity of 0.6 NTU after purifying treatment can meet the quality demands of sprinkling water for dustproof and cooling water for devices(GB 50215-2005), and the average mass concentration of TDS of 48 mg/L, SO_4^{2-} of 56.6 mg/L and total hardness of 9.8 mg/L after advanced treatment by RO can satisfy the quality requirements of preparing water for emulsion (MT 76-2002).
Keywords coal mine drainage, water treatment of underground mine, goafs, interacted washing filters, reverse osmosis, emulsion

Introduction

China is a serious water scarcity country，with water resources per capita accounting for 1/4 of the world average level. Most collieries are mainly distributed in the arid and semiarid regions of north and northwest of China. There are about coal mining areas of 70% with water scarcity, and 40% with serious water scarcity. In many coal mining areas, the shortage of water resources has limited the sustainable development of coal mining enterprises. However, accompanied by coal exploitation, a large amount of water must be discharged. According to the statistics, the discharged amount of coal mine drainage is 6.1×10^8 m^3 in 2010, and the utilized amount of coal mine drainage is 3.6×10^8 m^3 in China (Wang 2013) . It is an effective way to solve the problems of water scarcity in most coal mining areas by treating mine drainage as process water and domestic water. More than collieries of 95% adopt underground coal mining in China. Usually, mine drainage is drained from underground reservoirs to the treatment plant or station for purifying treatment on the ground by boosting pumps, then to the clear water tank by conveying pumps, after that to the water supply network underground by hydrostatic pressure as sprinkling water for dustproof, cooling water for devices and preparing water for emulsion (Zhou 2012). With the increase of mining depth, not only the length of boosting pipes from the water reservoir underground to the treatment plant or station on the ground gets longer and longer, but also the length of reusing pipes from the ground to the underground gets longer and longer. If coal mine drainage was directly treated and used underground coal mine, the cost for boosting coal mine drainage could be saved, the site areas for treatment facilities on the ground could be reduced, energy conservation and emission reduction could be realized, and obviously economic, environmental and social benefits could be achieved (Zhou 2013).

At present, there are few cases for directly treating and using coal mine drainage underground in China. Several cases mainly reduce the amount of dredging and expand the dredging cycle

of the underground water reservoirs. For examples, Liu Ji-wei et al.(2008) adopted the measures to remove most suspended solids from coal mine drainage by dosing coagulants before the entrance of the underground water reservoir, setting water retaining wall in the influent roadway, and overflowing after sedimentation from the top of retaining wall into subsequent sections of water reservoir. Guo Ji-zheng et al.(2010) used the purification technology of magnetic separation to remove most suspended solids from coal mine drainage before flowing into the underground water reservoir. Chen Wen-de et al.(2001) utilized the process combined coagulation with inclined tube sedimentation to remove most suspended solids from coal mine drainage before flowing into the underground water reservoir. Aimed to the characteristics of coal mine drainage quality and quantity, the conditions of goafs formed by coal mining and the actual situations of section size of underground roadway in Jining No.3 colliery, the process integrated goafs, an aeration oxidation tank with interacted washing filters is used to purify mine drainage in order to meet the demands of water quality for sprinkling water for dustproof and cooling water for devices. Small part of coal mine drainage purified is further conducted by advanced treatment of RO process to ensure the last effluent meeting the water quality standard for preparing emulsion, and to realize the goals of direct recycle and reuse of mine drainage underground.

Water quantity and quality

Water quantity

The coal mine drainage of Jining No.3 colliery mainly consists of underground gushing water, sprinkling water for dustproof and cooling water for devices. It is estimated that the amount of normal gushing water will be not less than 350～550 m^3/h in the next five years, which is stable about a long time. Based on the existing circumstance and long term planning for underground process water in Jining No.3 colliery, the purification capacity is 200 m^3/h and advanced treatment capacity is 6 m^3/h.

Water quality

The coal mine drainage of Jining No.3 colliery mainly contains suspended solids made of coal, rock powder and clay, with the features of black color, light specific gravity and slow settling velocity. The quality of raw coal mine drainage, the objective quality of purified water and the objective quality of advanced treatment water are listed in table 1.

Table 1 *The quality of raw mine drainage, purified water and advanced treatment water*

Items	pH	SS (mg/L)	TDS (mg/L)	SO_4^{2-} (mg/L)	Cl^- (mg/L)
Raw water	7.68-7.89	98-323	2279	1012	55
Purified water	6.5-8.5	≤30	/	/	/
Advanced treatment water	6-9	/	/	≤400	＜200

Purifying treatment system

Purifying treatment process

Jining No.3 colliery uses the exploitation mode of underground mining, which forms goafs after coal seams mined. The fillings in goafs mainly consist of sandstone, coal gangue, residual coal and clay with different diameters of grain. After coal mine drainage inducted into the goafs, most suspended solids and colloidal substance of mine drainage are retained by the actions of precipitation, filtration and absorption because of the huge space existed in the goafs, without dosing any coagulants. In the process of coal mine drainage flowing

through goafs, iron existed in the mineral substance dissolves into mine drainage in the form ferrous, by the actions of physical chemistry among mine drainage with rock, coal gangue and residual coal because of lack of oxygen in the goafs.

Coal mine drainage out from goalfs, which flows through aeration oxidation tank under the hydraulic force, is aerated by the perforated pipes laid at the bottom of the bank. The air resource is from pressure air pipes in the underground roadway, without special boosting equipment. Then aerated mine drainage flows into the interacted washing filters boosted by a pump. Under the catalytic actions of ferruginous activity films existed on the filtering media of filters, Fe^{2+} of mine drainage is rapidly oxidized into Fe^{3+} and hydrolyzed into $Fe(OH)_3$, forming a new catalyst to further remove iron ions of mine drainage. Effluent from filters flows into clear water tank by the hydraulic force. At last, mine drainage is boosted by supply pumps into underground water supply network as sprinkling water for dustproof and cooling water for devices.

Purification facilities and devices

Purification facilities and devices mainly include goafs, an aeration oxidation tank, interacted washing filters, power equipment, automatic control and instruments. Goafs have catchment areas of about 165,000 square meters and water storage space of about 980,000 cubic meters. The aeration oxidation tank is reconstructed by utilizing raw roadway of 10 m in No.6 mining area underground, with effective volume of 100 m^3 and hydraulic retention time of 0.5h. Interacted washing filters use parallel operation of two groups, and every group has 5 boxes with normal filtration rate of 6 m/h and compulsory filtration rate of 7.5 m/h. Power equipment contains boosting pumps, supply pumps and electrically operated valves. Automatic control and instruments consist of a PLC control cabinet and an upper computer installed in the control center.

Purification treatment effects

The purification treatment system of underground mine drainage in Jining No.3 colliery was come into use in June 2012, with average mass concentration of suspended solids (SS) of 210 mg/L in raw coal mine drainage and average turbidity of 0.6 NTU in purified effluent, meeting the water quality requirements of sprinkling water for dustproof and cooling water for devices. The system has the advantages of stable operation, high degree of automation and convenient operation and management.

Advanced treatment system

Advanced treatment process

In accordance with the demands of standard MT 76-2002, the water quality for preparing emulsion (aqueous hydraulic fluid) must be colorless appearance, no peculiar smell, no suspended solids and no mechanical impurities, and sulfate radical ions are less than or equal 400 mg/L. In contrast with the purified water quality and considering the underground working environment of fully mechanized mining faces, the advanced treatment process combined medium filtration with reverse osmosis is used in Jining No.3 colliery. The purified mine drainage comes from underground water supply network, and flows into medium filters through reducing valves. The effluent from medium filters flows into reverse osmosis devices without boosting pumps. And the effluent from reverse osmosis devices flows into finished production tank by hydraulic force as preparing water for emulsion.

Advanced treatment equipment

Advanced treatment equipment incorporates reducing valves, medium filters, reverse osmosis devices, pressure gauges, connecting tubes and valve parts, et al. Reducing valves reduce the

pressure of the water supply network to 1.0-2.5 MPa. Medium filters use 2 sets with filter elements of 10 μm. The material of membrane elements is aromatic polyamide, with the numbers of 12 and specifications of 8 inches. The material of production tank is stainless steel with volume of 3 m^3.

Advanced treatment effects

The underground advanced treatment devices of mine drainage in Jining No.3 are put to use in December 2013, with the average mass TDS of 148 mg/L, SO_4^{2-} of 56.6 mg/L, and total hardness of 9.8 mg/L, meeting the water requirements of preparing water for emulsion.

Conclusions

(1) The measures of underground coal mine drainage directly treated as sprinkling water for dustproof, cooling water for devices and preparing water for emulsion can reduce the amount of mine drainage emissions, save the boosting cost to the ground, consistent with the policies of energy saving and emission reduction, and have obvious benefits of economy, environment and society.
(2) According to the quality and quantity of coal mine drainage and working environment of underground roadway in Jining No.3 colliery, the purifying process combined goafs with an aeration oxidation tank and interacted washing filters can effectively remove suspended solids, colloidal substance and iron, can meet the quality requirements of sprinkling water for dustproof and cooling water for devices, without dosing any coagulants and special aerating devices for boosting air.
(3) Advanced treatment devices directly utilize the pressure of underground water supply network without electric equipment, and adopt the process combined medium filtering and reverse osmosis without any power devices. The effluent quality can meet the demands of preparing water for emulsion for fully mechanized mining faces, and solve the problems of corrosion, scaling and blocking of hydraulic supports and electro-hydraulic valves caused by preparing emulsion using untreated water.
(4) The technological process for purifying treatment and advanced treatment of coal mine drainage in Jining No.3 colliery has the characteristics of few facilities and power devices, high degree of automation, convenient operation and management, stable water quality of effluent, and low operation cost, etc.

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