COALMINE WATER TREATMENT TECHNOLOGY BY NATURAL SAND GROUND SYSTEM AND GOAF

YONG LIU, YA-JUN SUN and ZHI-MIN XU

School of Resource and Earth Science, China University of Mining and Technology
Xuzhou, Jiangsu 221116, China; E-mail: cumtliu@126.com)

ABSTRACT

Coal-mining destroys the groundwater aquifer, and when groundwater discharges into mine, it becomes mine water. When mine water was drained into the surface of the ground without necessary disposal, it causes many problems, for example, the low-efficiency of mine water utilizing, the shortage of water resources, and the environment pollution around mining areas. Since there are many coal mines in China, the shortage of water resources and the environment pollution caused by coal-mining becomes a serious problem. In order to solve these problems of coalmine water, it needs mine water treatment. In this paper, some general methods of mine water treatment are presented, and two major new methods are explained: one is the technology of mine water treatment by natural sand ground system in northwest of China, and this technology is based on the experiment of sand-filter; and the other is the treatment and utilization of mine water in goaf, and it is the means of using goaf to transfer and store mine water. Based on analysis of the mine water quality and the geology and hydrogeology condition in particular area, this paper expounds feasibility of the new methods, and compares and analyzes the characters of the two methods. The new technology of mine water treatment has important significance for making mine water become resources and protecting environment.

1. INTRODUCTION

Shendong coal mine area is located in the northwest of China. It is characterized by the typical feature of the arid and semiarid mainland monsoon type climate, the mean annual precipitation is less than 450mm, but the mean annual evaporation is more than 2000mm (Gui-jun, Y. and Lai, Z., 2000). In this area the surface water distributes differently to the last degree, which is obviously controlled by the seasons and ground, there are three rivers flowing through the mining area, whose runoff change greatly with the season and they have a low utilization rate; the ground water is limited by the distribution and development of aquifer with a small quantity.

The aquifer upon the coal seams and rich water zone of atmospheric crack bedrock are in the range of the fractured zone, If the shallow coal seams were mined, the aquifer will be destroyed seriously and groundwater turns into mine wastewater. If wastewater is discharged into the ground surface directly, it will pollute the surface water, so coalmine wastewater treatment and reuse are one method of relieving the contradiction of water resources.

2. QUALITY CHARACTERISTICS OF MINE WATER IN SHENDONG COAL MINE AREA

The groundwater in Shendong is caused by rainfall infiltration, which has great ability of dissolution with rich O_2 and CO_2. It mainly dissolves the carbonate minerals when infiltrating into the sand layer. Because Ca^{2+} is easy to be absorbed on the fissure surface when infiltrating into bedrock fissure, Na^+ will increase as the Ca^{2+} is replaced by Na^+ in water. Due to decarbonation, $CaCO_3$ will be precipitated. Meanwhile, for the bedrock fissure water is hard to flow, salinity will be increased due to the dissolution of rock for a long time.

There are several items over stand in mine water: turbidity, arsenic, petroleum, BOD_5, COD_{cr} and so on, which reflecting the quality characteristics of water changed because of pollution when groundwater transits into coalmine water.

3. EXPERIMENT OF SAND-FILTER

Shendong coal mine area is located in the southeast fringe of Mu Us Desert. There are lots of eolian sands on ground surface, so we can use the eolian sand to filter wastewater. It includes filtration, sorption and microbiological degradation, that degrades the organic compounds in water effectively, and renovating the pollutants and harmful components in mine water.

In order to find out the feasibility of this method, we took two water samples to treat with two-stage sand filter separately, we connected two 3m sand pinnacles in series and filtrated by injecting water. At last, we analyzed the quality of primary and secondary water separately.

Analysis of Experimental Results

The contaminations are turbidity, arsenic, petroleum, BOD_5, COD_{cr} in two water samples, which can be solved preferably by the experiment of sand-filter. Results are been shown in Table 1.

Table 1. Purification results of the adsorption filtration for overroof items in coalmine water

Coalmine	items	Primary adsorption filtration		Secondary adsorption filtration		Total removal rate (%)
		Detection value (mg/L)	removal rate (%)	Detection value (mg/L)	removal rate (%)	
Huo-jitu Mine	turbidity	80	38	10	88	92
	arsenic	1.00	0	no detection	100	100
	petroleum	0.68	53.7	0.22	68	85
	BOD_5	4.66	35	3.58	21.8	50.0
	COD_{cr}	21.8	28.5	14.1	35.3	53.8
Hei-longgou Mine	turbidity	25	93	15	40	96
	petroleum	0.25	46.8	0.09	64	81
	BOD_5	4.26	15	3.86	9.4	23.0
	COD_{cr}	16.8	17.2	15.0	7.1	23.2

We can see that the removal rates of BOD_5 of the two samples are 50% and 23%. The removal rates of COD_{cr} reach 53.8%and 23.2%.There is 1.00 mg/L arsenic in Huo-jitu Mine, and there is no detection in Hei-longgou Mine, the removal rate of arsenic is 100% in Huo-jitu Mine. simultaneously; the removal rates of turbidity are 92% and 96%. The removal rates of petroleum are 85% and 81%.The results of sand filtration experiment show that it is satisfied purification of mine water by the performance of adsorption filtration of sand layer.

Experiment of Sand-Filter Effected by Sand Layer Thickness and Hydraulic Retention Time

We know that sand filtration has good treatment efficiency; however, the influences of the thickness of sand layer and hydraulic retention time need to be analyzed and demonstrated for further. The following experiment was completed in the filtering cylinder. First, we put the filter supporting bed on the bottom of filtering cylinder. Then we filled the screened eolian sand into the experimental tubes (length as 2m). The mine water was filtered after being transmitted by the constant flow pump in the filter column. Then the water was preserved to determinate water quality index after the flow has been stable for three times at last.

The Effect of Sand Layer Thickness on Sand-Filter

We performed the filtration experiment with 4 kinds of sand layer with different thickness for finding out the effect of filtration and the influence of sand layer’s thickness. When the thickness of sand begun from 180cm decreased to 50cm with the same flow, the results are shown as follow.

Table 2. The effect of sand layer thickness on sand-filter

Thickness of sand layer/ cm	Flow/ml·h $^{-1}$	COD_{cr}	Suspended solid	Chromaticity color/times
		/mg·L^{-1}		
180	151	9.21	no detection	no detection
150	151	9.45	no detection	no detection
120	151	10. 16	no detection	no detection
100	151	11. 27	no detection	no detection
50	151	29. 21	no detection	no detection

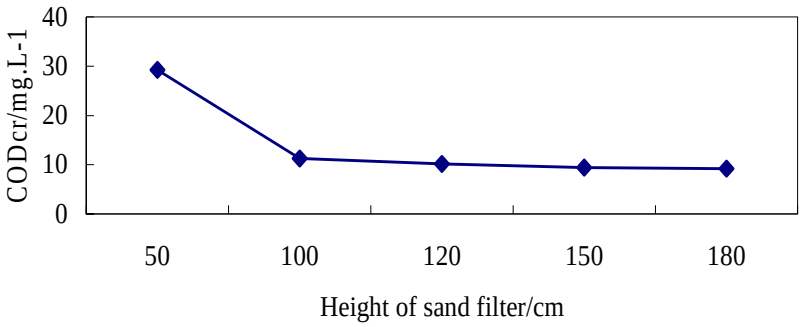

Figure.1 The effect of sand layer thickness on removal of COD_{cr}

As we see from Fig.1, eolian sand is effective for mine wastewater purification. The thickness changed from 180cm decreased to 50cm and the detection results all meet the requirements of reuse water. The thicker the sand layer is, the better the removal effect is, it is because more pollutants will be absorbed and intercepted if the seepage path is long enough.

It suggests that eolian sand has a strong absorb ability and great filtration effect, and that wastewater can be purified by interception for a short distance, reaching the standard of wastewater reuse.

The Effect of Hydraulic Retention Time on Sand-Filter

According to the experiment above, the sand layer has efficiency on purification when it is 120cm, the treatment effect improves little with increasing the sand layer thickness; therefore, we study the influence of different hydraulic retention time as the sand layer is 120cm. The data of the experiment is shown in Table 3. The efficacy of removal COD_{cr} with different hydraulic retention time is drawn in Fig.3.

Table 3 The effect of hydraulic retention time on sand filter

Height of filtration sand layer/ cm	Flow rate /ml·h $^{-1}$	retention time /h	COD_{cr}	Suspended solid	Chromaticity color/times
			/mg·L^{-1}		
120	1080	0. 79	26.05	no detection	no detection
120	900	0.95	22.67	no detection	no detection
120	510	1.67	18.05	no detection	no detection
120	378	2.26	16.45	no detection	no detection
120	151	5. 65	10.16	no detection	no detection

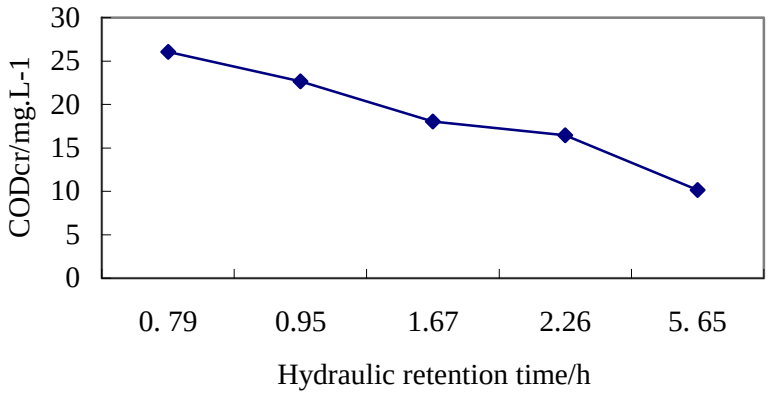

Figure.2 The relationship between retention time and COD_{cr} value

It can be concluded that the removal effect is better if the retention time is longer, because the disturbance to filter bed is less due to water flows more slowly when the time is longer with the same path.

The Effect of Concentration of Mine Wastewater on Sand Filter

To find the effect of various concentrations of mine wastewater on sand layer, we performed experiment with different concentrations mine wastewater. The results are shown as follow.

Table.4. Purification efficiency of different COD_{cr} concentration water

Height of sand layer/ cm	Concentration of COD_{cr}/mg·L^{-1}		Chromaticity color/times	Suspended mater
	Before purification	After purification		
100	127. 59	7. 99	no detection	no detection
100	1 777. 90	16. 43	no detection	no detection
100	3 324. 55	15. 01	no detection	no detection

We can see from Table.4 that eolian sand is effective in removing the suspended mater, chromaticity, COD_{cr} in Shendong Coal Mine Area, which can serve as the main material for mine wastewater treatment.

4. NATURAL SAND GROUND SYSTEM

Methodology

Natural sand ground system is to select favorable topography, tectonic position (beneficial for catchments), inject the wastewater into sand layer through the water injection hole or ditch, and then ultimately purify wastewater with the adsorption properties and permeability of the sand particles by permeating and flowing naturally (Xiaolu, Z. *et al.*). Simultaneously, we can take out the purified water with the method of collecting, drilling, ditch or brief precipitation. The major flowchart is shown in Fig.3.

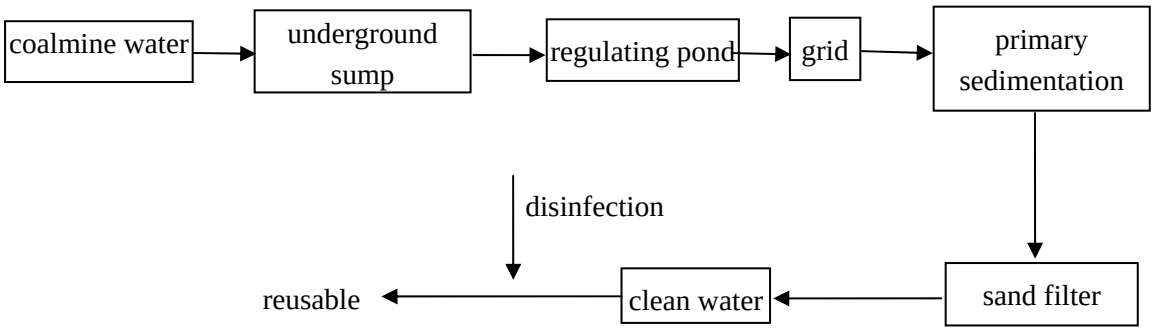

Figure.3 Schematic diagram of sand-filter process

Favorable Structure and System

Favorable water storage structures possess not only fairly good bed of water insulation to prevent leaking in the purification process, but also appropriate structural shape, which is good for permeation, collection and recycling. Such as follows.

Various basins, depression, include: water-resisting footwall; sag, depression, accumulation of sand overlying in topography and geomorphology. The water can flow around or be pumped into the center or perforate to inject water around the basin if necessary.

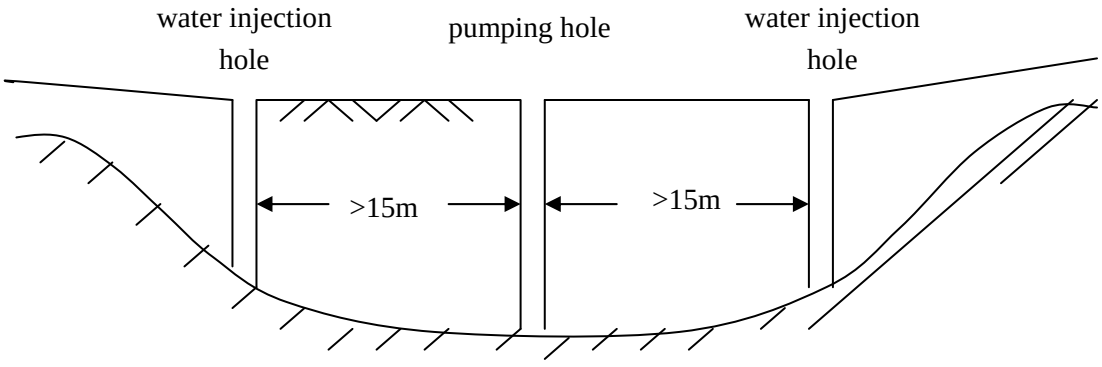

Figure.4 Schematic diagram of filtration adsorption in sag basin

Three-side ditches and valleys, planar graph and profile are shown in Fig.5 and Fig.6. Drill water injection hole or excavate water flood canal on the upstream of the ditch, valley and suction eyes or catch drains in the exit port to head off the purified water. The water injection hole will be over 15m away form suction eyes.

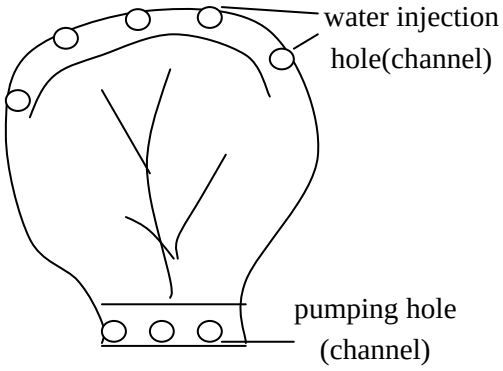

Figure.5 Plane graph of ditch and valley

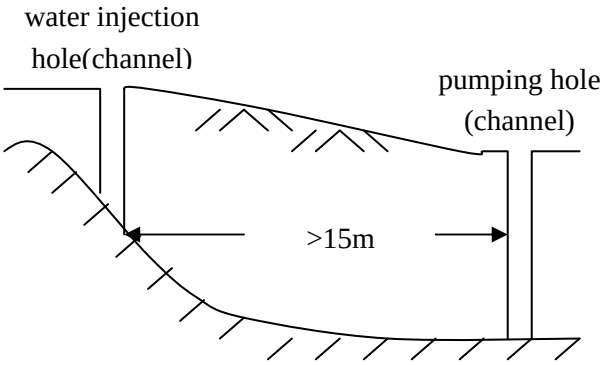

Figure.6 Profile of ditch and valley

Drill water injection hole along the river or ditch at a certain distance in the area without above mentioned topography and geomorphology. Water flows into the river directly by adsorption filtration for a section distance as shown in fig.7. It has important significance for supplying the inadequate water resource, protecting environment and water resource. However, secondary pollution should to be avoided.

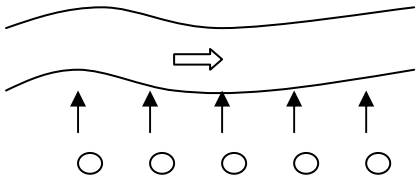

Figure.7 Schematic diagram of river catchments

5. THE TREATMENT AND UTILIZATION OF MINE WATER IN GOAF

Processing in the goaf is applicable besides sand filtering. We built a small goaf strata model with hydraulic gradient in the laboratory to filter he mine water, then took 21L homogeneous mine water whose turbidity was approximately 1560, dispose the water by the model as the average flow Q = 1.215L/min. As the key pollutant is suspended matter in mine water, this paper only discusses the removal effect of turbidity, results are shown as follow.

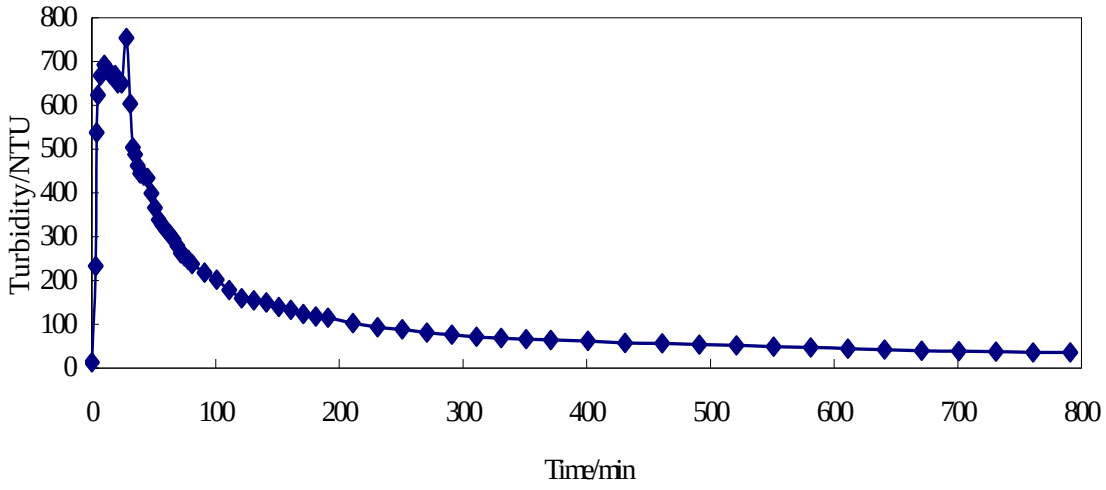

Figure.8 Effect drawing of the purification experiment for homogeneous mine water

The results show that the turbidity of effluent is 13 initially, because the filter material retains a small amount of constitution water caused by flushing with tap water. The initial effluent is tap water actually which is extruded when mine water flowing into the filter bed. The turbidity of effluent increases to the first peak (692) from 13, which is much less than raw water (1560); mine water turbidity decreases significantly owing to the filtration when flowing. On this account, turbidity shows an increasing trend though lower than raw water, and then decreases at small amplitude arriving the second peak (754) until the residual water was exhausted from filter clogging pocket, which is caused by mixing of muddy water cycled to filter clogging pocket and pure mine water. After that , turbidity tends to stationary drop after a dramatic decrease, and keeps on steady at last (36).

The experiment results show that treatment in the goaf model acquires preferably effect with 97.69% as the total turbidity removal rate; the process lasts for 791 minutes, treatment efficiency enhanced in compare with time rising. Treatment effect reduces after many times of filtering. Washing filter clogging pocket can recover the purification effect significantly. Even though decontamination ability weakens along with more filtering times, the removal rate of turbidity kept higher than 95%. In fact, the real goaf is longer and thicker than the model with larger treatment capacity and well developed pore. Therefore , the actual removal rate of turbidity is higher than the experiment result, purifying mine water in the goaf not only saves investment of construction and operation cost, but also improves the removal rater of SS.

Goaf is considered as watershed, using the underground sump as water purifying tank, injected the purified water in goaf into the sump by water injection hole to supply water underground, making mine wastewater become resources, which can meet the water demands of mining underground basically. The technological process is shown in fig.9.

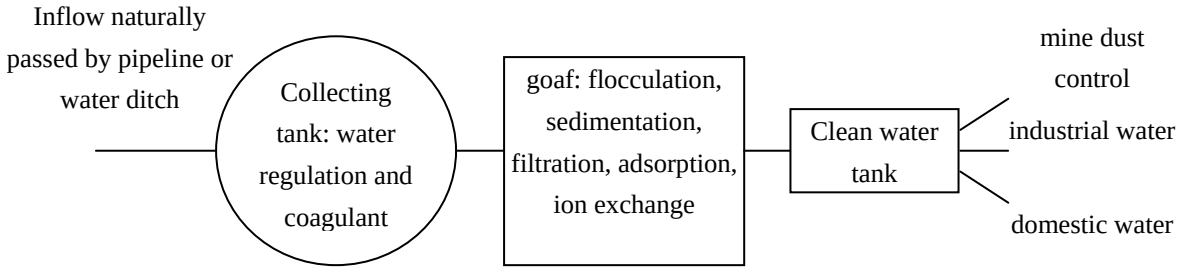

Figure.9 Process chart

6. CONCLUSION

The design technology of mine water treatment should be chosen by the quality characteristics. In the northwest arid area of China , mine water can be purified by natural sand ground system or in goaf. Through the experiment and application, the results show that the two methods are of great significance in mine water treatment with simple process, stable removal effect and lower cost.

7. REFERENCING

Gui-jun, Y., and Lai Z. (2000) “The main hydro-engineering-environmental-geological problems arose from the exploitation of coal resource in Yu-Shen-Fu mine area of northern shanxi and their prevention measures.” Journal of Engineering Geology, 8(4), 446-455.

Xiao-lu, Z., Ping, Z., Tao, L. and Xue-lan C. (2006) “Research on coal mine wastewater resources in Shenbei coal mine area.” Journal of Shanghai University of Electric Power, 22(3), 246-248