Study on Discrimination Model of Water Inrush Source in Binhuang Mining Area of China

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Abstract. Groundwater flow into the mine by coal mining, which threatens the safety of coal mine. Therefore, it is necessary to identify the source of the water flowing into the coal mine. Taking binhuang mining area in Shaanxi Province as the research background, the discrimination models of six water inrush sources had been studied. The composition of 256 water samples was determined and the water quality characteristics of 6 water sources were analyzed. Fisher linear discriminant function model was established by selecting 9 indexes of water quality components. By testing the discriminant effect, it is considered that the probability of K1L aquifer misjudging as Q aquifer and surface water is high, and the misjudgment rate is 30.4%. Combined with the analysis of geological conditions, it is considered that K1L aquifer has a good hydraulic connection with Q aquifer and surface water. Aiming at the problem of misjudgment, the neural network analysis model is used, and the misjudgment rate is reduced to 0%.

1 Introduction

The hydrogeological conditions of coalfields in China are very complex and often threatened by water disasters[1-3]. Water disaster affects production and even damages people due to well flooding. Before the occurrence of major water inrush in coal mine, there are always some omens[4-6]. In particular, if the precursor of water inrush information can be timely analyzed and studied by using hydrogeochemical theory, it is of great significance to identify the source of water and judge the possibility of water inrush. Rapid and accurate identification of water inrush source is the guarantee of coal mine safety production and the premise of mine water prevention and control work.

Therefore, scholars have carried out a large number of research on the discrimination of water inrush sources in coal mines. In terms of methods, there are different statistical methods to identify water inrush sources: for example, the distance discrimination method is used to identify water inrush sources, and the fuzzy comprehensive evaluation method is used to identify water inrush sources. In the discrimination of data sources, there are different test results for discrimination, such as using water quality dynamic curve to predict water inrush source, using conventional water quality to identify mine water inrush source, using trace elements to identify water inrush source in Linhuan Mining Area, and the application of organic matter in water inrush source discrimination.

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Although a large number of research results have solved the technical problem to a great extent, due to the great difference of groundwater environment in different regions and the different application scope of different methods and data sources, it is necessary to compare different statistical methods and data sources to study the water inrush source discrimination model suitable for the study area.

2 Overview of the study area

2.1 Location of study area

The Binhuang mining area of Huanglong Jurassic Coalfield is located in the southern margin of Ordos Basin and the southwest of Loess Plateau in Northern Shaanxi, which belongs to the Yellow River system. The study area is about 280km long, 30-40km wide, with a total area of nearly 8000km^2 and a total coal bearing area of about 6569 km^2. It is one of the important coal bases in Shaanxi Province, China.

2.2 Hydrological characteristics of the study area

The study area belongs to Ordos Cretaceous Artesian Basin, which is the groundwater system of the Loess Plateau and the Cretaceous fracture pore aquifer system.

In addition to surface water, the main aquifers from top to bottom are as shown in Figure 1: Quaternary pore aquifer (Q); Fracture aquiferof Huanhe formation in Huachi, Cretaceous (K1h); Cretaceous Luohe formation sandstone aquifer (K1l); Sandstone aquifer in the lower part of Jurassic Zhuluo formation (J2z); Jurassic Yan'an formation sandstone aquifer (J2y).

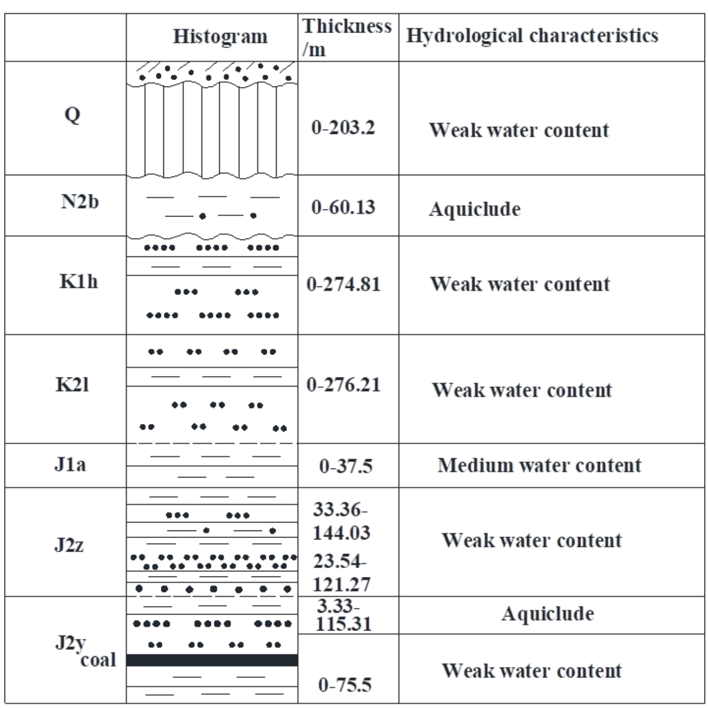

Fig. 1. Comprehensive hydrogeological histogram of Huangling mining area

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3 Water sample acquisition and water quality characteristics

3.1 Water sample acquisition and testing

The water samples collection in the research area involves the coal mines including Huangling No.1 mine, Huangling No.2 mine, Chenjiashan mine, Xiashijie mine, hujiahe mine, wenjiapo mine, Xiaozhuang mine and Dafosi mine. The water samples are taken from surface water, Quaternary aquifer (Q), Cretaceous Huachi Huanhe formation fissure aquifer (K1h), Cretaceous Luohe formation sandstone aquifer (K1l), lower Jurassic Zhiluo Formation sandstone aquifer (J2z), Jurassic Yan'an Formation coal series aquifer (J2y). The self-made collector (Fig. 2) is used for this sampling, and the boreholes involved are also various, long-term observation holes, hydrological holes and exploration holes.

Fig. 2. Sampling device

The analysis and test items include seven ions (K^{+}, Na^{+}, Ca^{2+}, Mg^{2+}, HCO_3^{-}, SO_4^{2-}, Cl^{-}, Fe^{2+}, Fe^{3+}, $A1^{3+}$, NH_4^{+}, CO_3^{2-}, NO_3,NO_2) in groundwater. Groundwater is extracted by self-made water extractor, which has been acid cleaned before use, and then the extracted water sample is poured into the sampling bottle which has been treated in advance. For the sampling of main cations, strong nitric acid with pH < 2 should be added as soon as possible, and acidification is not needed for the sampling of main anions. The sampling bottle needs to be cleaned more than three times with the groundwater sample to be taken. Samples need to be stored in a clean environment. The pH, temperature and conductivity of the samples were measured in the field. The simple analysis and test of water quality are completed in the laboratory, and the test equipment includes ion chromatograph and water quality rapid analyzer.

3.2 Water quality characteristics

According to the overall characteristics of groundwater chemistry in the study area, the hydrochemical type of groundwater in the Quaternary loose layer is relatively single, and most of them are HCO_3-Ca, HCO_3-Ca · Mg or HCO_3-Ca · Na type water (see Figure 3). The pore water of Luohe formation sandstone is mainly SO_4-Na or SO_4 · Cl-Na type water, and the groundwater salinity is more than 1g / L. The reason is that the speed of groundwater runoff is slow and the cycle period is long. For the underlying bedrock fissure water, the aquifers are mainly anding formation, Zhiluo Formation and Yan'an formation of Middle Jurassic system, and the water quality has some similar characteristics. Specifically, the groundwater in Huangling and Binchang areas is mainly SO_4-Na, SO_4 · Cl-Na and Cl-Na, while the groundwater in Chenjiashan and Xiashijie mines in Jiaoping mining area is mainly HCO_3-Ca · Na. The main reason is that when the bedrock is directly exposed to the surface or located in the recharge area, the groundwater runoff is strong, mainly HCO_3-Ca type water, and the mineralization is low. When the bedrock is overlaid with other strata, the groundwater runoff is weak and the flow rate is slow, and the concentration of dissolved salts in the water increases significantly due to the long-term interaction with the rock dissolution. Most of them are Na-SO_4 type water with high salinity.

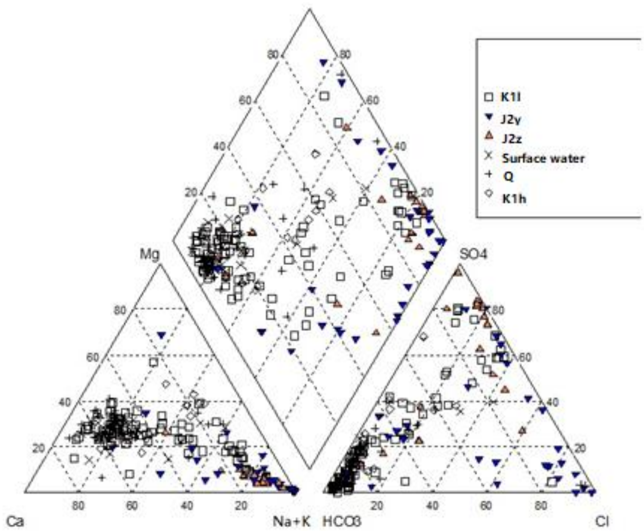

Fig. 3. Piper diagram of sample water chemistry

4 Water source discrimination model and verification

4.1 Fisher water source discrimination model and verification

The new Fisher discriminant analysis method is used to identify the aquifer, so as to comprehensively identify the aquifer from multiple angles and models, and test the effect of the model. Taking 256 groups of data tested in the study area as training samples, the simultaneous calculation method was selected, Wilk's lambda was selected to evaluate the significance of the model, the discriminant Z score of each observation was calculated, the difference of discriminant Z score of each group and the prediction accuracy of the relationship between the evaluation group and each group were tested, and then the software was run for calculation.

After F-test, box's test and Wilk's lambda test, the Fisher linear discriminant function model is obtained under the premise of the same prior probability.

$$y_1 = 0.003x_1 + 0.058x_2 + 0.035x_3 + 0.002x_4 + 0.003x_5 + 0.007x_6 - 0.004x_7 - 0.01x_8 + 25.38x_9 - 104.51$$

$$y_2 = 0.003x_1 + 0.055x_2 + 0.032x_3 + 0.002x_4 + 0.003x_5 + 0.007x_6 - 0.003x_7 - 0.08x_8 + 24.52x_9 - 97.73$$

$$y_3 = 0.002x_1 + 0.42x_2 + 0.07x_3 + 0.002x_4 + 0.003x_5 + 0.007x_6 - 0.003x_7 - 0.08x_8 + 24.24x_9 - 96.02$$

$$y_4 = 0.001x_1 + 0.052x_2 + 0.048x_3 + 0.002x_4 + 0.003x_5 + 0.007x_6 - 0.003x_7 - 0.09x_8 + 25.1x_9 - 102.6$$

$$y_5 = -0.006x_1 + 0.086x_2 + 0.01x_3 + 0.002x_4 + 0.003x_5 + 0.007x_6 - 0.011x_8 + 25.64x_9 - 113.88$$

$$y_6 = 0.003x_1 + 0.06x_2 + 0.035x_3 + 0.002x_4 + 0.002x_5 + 0.007x_6 - 0.003x_7 - 0.015x_8 + 25.96x_9 - 111.74$$

By substituting the data of potassium and sodium ion (x1), calcium ion (x2), magnesium ion (x3), chloride ion (x4), sulfate ion (x5), bicarbonate ion (x6), salinity (X7), total hardness (x8) and pH value (x9) in a group of water samples into the above seven functions, the seven values of seven types of aquifers can be obtained respectively, and the largest of the seven values can be obtained, The water sample belongs to this kind of aquifer.

It is found that a single discriminant function can not effectively discriminate all aquifers. Among them, the discriminant effect of surface water is 72.7%, Q is 68.2%, K1h is 52.9%, K1l is 17.4%, J2z is 52.6%, J2y is 42.9%. The K1l aquifer misjudged the Quaternary aquifer and surface water, the discrimination rate is as high as 30.4%. There is a certain degree of lack of Cretaceous Huachi formation and Neogene clay layer in the study area. The groundwater of Luohe formation is more directly recharged by Quaternary phreatic water and surface water, which should be the reason for the misjudged quaternary phreatic water and surface water of Luohe formation.

4.2 Water source identification and verification of BP network algorithm

Eight groups of water samples of K1l aquifer known in Huangling No.2 mine are selected. According to the applicable conditions of the model, when the number of think tank samples is large, it is suitable for the system cluster analysis and neural network analysis. Therefore, the system cluster analysis and neural network analysis are selected to test whether the analysis result is K1L aquifer. The common characteristic ions: Na^+, Ca^{2+}, Mg^{2+}, Cl^-, SO_4^{2-}, HCO_3^-, salinity, total hardness and pH value were selected as the grouping variables. Then, according to the sample situation, when there are iron ions (Fe^{2+}), carbonate ions (CO_3^{2-}) and ammonium ions (NH_4^+), the discrimination index is increased.

Using neural network analysis, the accuracy of the analysis results is 100% (as shown in Table 1).

Table 1. Discriminant analysis results of mathematical model

No.	Borehole number	Real aquifer	Discriminant aquifer
10000123	FX35	K1l	K1l
10000128	S1	K1l	K1l
10000129	S1	K1l	K1l
10000197	K8	K1l	K1l
10000198	J1	K1l	K1l
10000200	J3	K1l	K1l
10000201	J4	K1l	K1l
10000203	B1	K1l	K1l

4.3 Discuss

The results show that: BP network algorithm model has better accuracy than Fisher linear discriminant function model. On the one hand, because of the natural hydraulic connection between aquifers, it is difficult to accurately distinguish the source of water inrush by simple linear discriminant function[7]. On the other hand, the neural network model in judging the feasibility of water inrush source, the analysis results and process are close to the thinking process and analysis method of human brain, reflecting the powerful intelligent processing function, and has incomparable advantages in solving nonlinear problems. Therefore, the BP network algorithm model is more suitable for the special hydrogeological characteristics of the study area.

5 Conclusion

There are some errors in water source identification by Fisher discriminant analysis, especially in K11 aquifer. The error rate is as high as 30.4%. Using neural network analysis, this kind of misjudgment disappears.

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References

[1] T. Li, S.Wang, L. Han, et al., “Reasonable thickness of protected loess under loose aquifer in ecologically fragile mining area,” *Journal of China Coal Society*, vol.42, no. 1,pp. 98-105,2017.

[2] L. Ma, X.Du, F. Wang, et al., “Water-preserved mining technology for shallow buried coal seam in ecologically-vulnerable coal field: A case study in the Shendong coal field of China,” *Disaster advances*, vol.6, pp. 268-278,2013.

[3] V. Palchik, “Experimental investigation of apertures of mining-induced horizontal fractures,” *International Journal of Rock Mechanics and Mining Sciences*, vol.47, no. 3,pp. 502-508, 2010.

[4] S. Zhang, Y. Liu, “A simple and efficient way to detect the mining induced water-conducting fractured zone in overlying strata,” Energy Procedia, vol.16, pp. 70-75, 2012.

[5] V. Palchik, “Localization of mining-induced horizontal fractures along rock layer interfaces inoverburden: Field measurements and prediction,” *Environmental Geology*, vol.48, no. 1,pp. 48, 68-80, 2005.

[6] J. Li and C. Liu, “Formation mechanism and reduction technology of mining-induced fissures in shallow thick coal seam mining,” *Shock and Vibration*, vol.2017, no. 6,pp. 1-14, 2017.

[7] T. Li, J. Zhang, Y. Gao, et al. “Hydrological Characteristics of Ordovician Karst Top in a Deep Region and Evaluation of Its Threat to Coal Mining: A Case Study for the Weibei Coalfield in Shaanxi Province, China” *Geofluids*, vol.6, pp.1-17, 2020.