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Common Discrimination Method and Evaluation of Water Inrush Source in Mine

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Abstract. Discrimination of mine water inrush source has always been the focus of academic circles. In order to do a good job in mine water inrush prevention and control, it is necessary to find out the source of mine water inrush. Combining with the relevant research results in recent years, this paper focuses on discussing several commonly used methods for identifying mine water inrush sources, such as conventional hydrochemical characteristics discriminant method, isotope analysis method, distance discriminant analysis method, BP neural network method, etc, pointing out their respective advantages and disadvantages. It is concluded that each method has its limitations, selection and determination methods should be based on the actual situation of hydrogeology and comprehensive utilization of various methods, which can greatly improve the accuracy of water inrush source identification and overcome the shortcomings of single method. It can provide some reference and guidance for related research work.

Introduction

In coal mining and production, mine water inrush is one of the most important mine safety disasters, which is parallel with fire, gas and other accidents. It has been a serious threat to the safety of coal mining for a long time, how to find out the cause of water inrush timely and accurately and determine the source of water inrush is the primary problem to solve and further prevent water inrush accidents, and also the precondition to do a good job of follow-up treatment work[1].

To distinguish the source of mine water inrush, it is necessary to comprehensively consider the hydrogeology and geological structure conditions of the mining area, and make full analysis by using the basic data of hydrochemistry, water temperature, water level and so on[2].Among them, hydrochemical data is the most objective reflection of groundwater characteristics. Water quality data can be used to identify water sources accurately, quickly and economically[3].In recent years, the discriminant analysis method of mine water inrush source has developed rapidly. From the initial environmental isotope analysis method and conventional hydrochemical characteristics discriminant method, multivariate statistical analysis method (distance discriminant analysis method, etc) and non-linear identification method (BP neural network method, etc) have been gradually created. These methods complement and verify each other, which is the main method of water source discrimination at present[4], and also makes the theory of water source discrimination step into a mature stage gradually. This paper will mainly elaborate and evaluate the methods listed above.

Discrimination Method of Conventional Hydrochemical Characteristics

Detailed Description of the Method

The hydrochemical characteristic discriminant method is a method to determine the source of water inrush by studying the hydrochemical characteristics (main ion characteristics) of each aquifer.
This method focuses on three main cations Ca^{2+}, Na^{+}, $Mg^{2+}$and three main anions HCO_3^{-}, SO_4^{2-}, Cl^{-} etc and draws Piper three-line map according to the milligram equivalent percentage of six ions (as shown in Fig.1). For example, the water quality types of aquifers are classified according to Shug kalev classification, and then the Kurllov's formula of water inrush point and aquifer water samples

is compared. To determine which aquifer is similar to the water quality of the water inrush point, the source of the water inrush can be identified. The basic model is: determination of water quality type; analysis of main cation concentration; analysis of main anion concentration; determination of mineralization degree and hardness; according to standards determination of characteristic ratio. Li Mingshan and others used the hydrochemical characteristic model to accurately identify the water inrush source of Yaoqiao mine, and thought that the method was simple and fast, and could be popularized and applied.

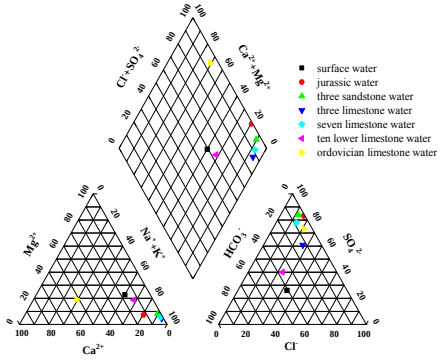

Figure 1. Piper three-line chart of water quality of each aquifer (according to data in document [5])

Method Evaluation

This method distinguishes water inrush sources by specific data and charts, which is more intuitive and accurate, but only when the water source is single and the hydrochemical characteristics among aquifers are different, the discriminant effect is obvious. In order to further improve the reliability of the method, isotope tracers are needed to verify the method. The method has high reliability, but the discriminant effect is obvious when the water source is single and the water quality characteristics between aquifers are different.

Isotope Analysis

Detailed Description of the Method

In the judgment of mine water inrush source, isotope analysis is a method that mainly uses O^{18}, D, T isotopes to determine the water inrush source. As a result of isotope fractionation, all kinds of natural water have different isotope characteristics, so the source and origin of water can be determined by D and O^{18} in water. The basic models are as follows: stratified sampling according to need and simultaneous testing of ^{2}H, ^{3}H, ^{18}O isotopes and chemical components in samples; Piper three-line map which can show the hydrochemical characteristics of all water samples by testing data description; Combining with the national precipitation line equation $\delta(D) = 7.9\delta(O) + 8.2$, the correlation diagram of D and ^{18}O values is drawn (as shown in Fig. 2); correlation map of D and O values with national atmospheric precipitation line according to the triple-line map The hydraulic relations between different aquifers and between aquifers and surface water are analyzed to determine the source of water inrush. By measuring and comparing the values of precipitation, natural water, groundwater and surface water O^{18} and D, we can not only explore the recharge source of groundwater, but also find out whether there are hydraulic connections among aquifers, and determine the proportion of water from different sources after fusion. At present, this method has achieved good results in mine water control practice[6].

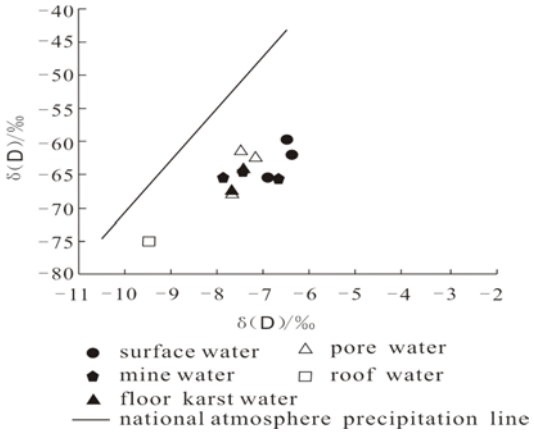

Figure 2. Correlation diagram of δ(D) and δ (O) values (based on reference [7]data)

Method Evaluation

It is more accurate and rapid to distinguish the source of water inrush, but it requires that the D, ^{18}O and T isotopes of each aquifer vary greatly, otherwise the result of the impact analysis will be affected. In addition, because of its high cost, this method is generally not used.

Distance Discriminant Analysis

Detailed Description of the Method

The basic idea[8] of distance discriminant analysis is to summarize the regularity of objective classification according to the data information of several samples of each known category, and construct a discriminant function. Then, according to the generalized discriminant function, the new sample function can be distinguished. The main contents of this discriminant method are Markov distance, distance judgment of two whole, distance judgment of multiple whole and evaluation of judgment theorem. The basic model (as shown in Fig.3) is to determine the characteristic ions participating in the modeling according to the specific conditions, classify the mine water inrush sources according to the water quality characteristics of each aquifer, select the water sample data for learning and training, take the characteristic ions determined at the beginning as the input layer unit, take the water inrush source classification as the output layer unit, and rely on distance discriminant analysis related theoretical formulas. Discrimination and calculation are carried out. After calculating and discriminating, the corresponding discriminant coefficient can be obtained, and then the discriminant function can be obtained. Liu Jinhai and others have used this method to solve the problem of top coal caving identification in steeply inclined seams by modeling. They believe that this method has high accuracy and good classification of models.

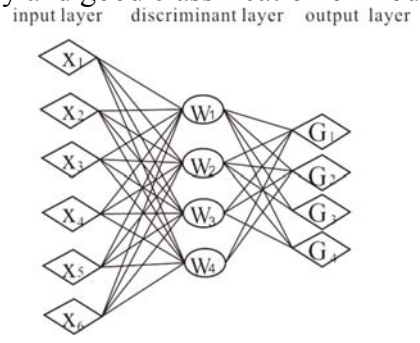

Figure 3. Distance discriminant analysis model diagram

Method Evaluation

The method is simple and easy to use, but ignores the weight of the discriminant method and the whole, and the characteristics of each sample are not well reflected.

BP Neural Network Method

Detailed Description of the Method

Because the artificial neural network can show extremely complex dynamic behavior, and has high fault tolerance and non-linearity, it is more and more widely used today with the rapid development of high-tech. It has played a huge role in signal processing, control engineering and other fields. After testing the neural network with a certain amount of data, the purpose of predicting the unknown data can be achieved by inputting the known data into the network. Therefore, this method plays a positive role in the field of disaster prediction[9].At present, in the practical application of artificial neural network, the most frequently used is BP neural network. BP neural network is a multi-layer back-propagation neural network system trained by error back-propagation algorithm. Three-layer structure network is commonly used, and its structure chart is shown in Fig. 4.

Compared with the traditional statistical analysis model, the BP neural network model has better predictability and persistence. The basic models used in the identification of mine water inrush sources are as follows: selecting the main discriminant factors according to needs (characteristic ions, such as Ca^{2+}, Mg^{2+}, SO_4^{2-}, Cl^-, etc); determining the number of neuron nodes in each layer according to the actual situation; assigning random initial values for the connection weights of the neural network and the threshold of the neuron nodes; Define the meaning of parameters; select samples for learning and training; input the factors to be judged into the training neural network for discrimination.

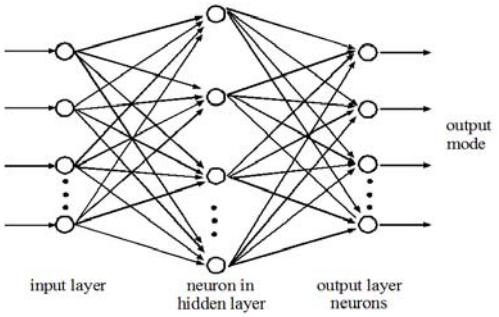

Figure 4. BP neural network structural diagram

Method Evaluation

The results of discrimination are more objective and accurate, but learning and training need a large number of effective samples, and the selection and training process of samples is difficult and complex.

Other Methods

In addition to the above methods, Lu Jintao et al. combined principal component analysis with Fisher discriminant analysis model for the first time to discriminate the water inrush source, and achieved good results; Feng Dongmei et al. used correlation theory and support vector machine to effectively solve the problem of scattered and multi-dimensional decision matrix caused by too many original indicators in mine water Inrush Source discrimination.

Summary

The common discriminant methods of mine water inrush source include conventional hydrochemical characteristics discriminant method, isotope analysis method, distance discriminant analysis method, neural network method, etc. When selecting a method to discriminate mine water inrush source, the actual situation of mine hydrogeology should be taken as the basis. Through analysis, it is concluded that if a variety of evaluation methods are combined to clarify the source of mine water inrush, the limitations of various methods will be avoided, and the accuracy of water inrush source identification will be improved to a large extent.

Acknowledgement

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