

# Risk Assessment of Floor Water Inrush in Deep Mine Based on Grey System Theory

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## Abstract

In the paper, the comprehensive research was composed of main controlling factors of floor water inrush in deep mine, method of floor water inrush risk assessment and risk assessment system, which was carried on three aspects of the deep seam mining floor water inrush factors analysis, the mathematical model establishment and system programming, based on the Grey system theory. Using the investigation, data assessment, statistical analysis and numerical analysis method, it got the influent factors of floor water inrush in deep mine; By the analytic hierarchy process (AHP), it determined the main controlling factors and their weights. It also determined the accuracy of the main controlling factors and verified their weights of these factors by the Grey relevance analysis. It set up deep mine's floor water inrush risk assessment model through the establishment of membership and the membership function of each main controlling factors deal with information data, according to the Grey matter-element model. And it was tested by practical engineering samples to gain the reliability degree of the established model, which can provide guidance and basis for mining safety.

**Keywords:** deep mine; floor water inrush; Grey system theory; risk assessment

## 1. Introduction

Gradually to the deep coal mining in our country development, water inrush issues occurring in the process of deep coal mining as the major hidden danger of the mine safety production. In order to predict floor water inrush effectively, and guide the mine safety.

## 2. Determine the main controlling factors of floor water inrush in deep mine

This paper analyzed the main controlling factors of floor water inrush in deep mine from five aspects: hydrogeology, water structure, floor water-resisting layer, mining conditions and the characteristics of deep mine. Then we obtain the main impact indicators: water pressure of aquifer, watery of aquifer, the degree of strong water supply, fault hydraulic conductivity, fracture development situation, thickness of water-resisting layer, water-resisting layer lithology combination, floor stress state, mining thickness, mining depth, slant distance of working face, working face advancing distance, characteristics of deep mine(three "high" and one "disturbance"), etc.

## 2.1 Weights determination of floor water inrush influence factors in deep mine based on analytic hierarchy process

Through the analysis of the factors affecting floor water inrush in deep mine, then establish a index system of deep

mine's floor water inrush<sup>[6]</sup>(Fig.1). According to the structure at all levels of judgment matrix, consulting experts in the field of water inrush prevention, in combination with 1 to 9 scaling method, by comparing two factors to determine the weight value of various influencing factors(Table 1).

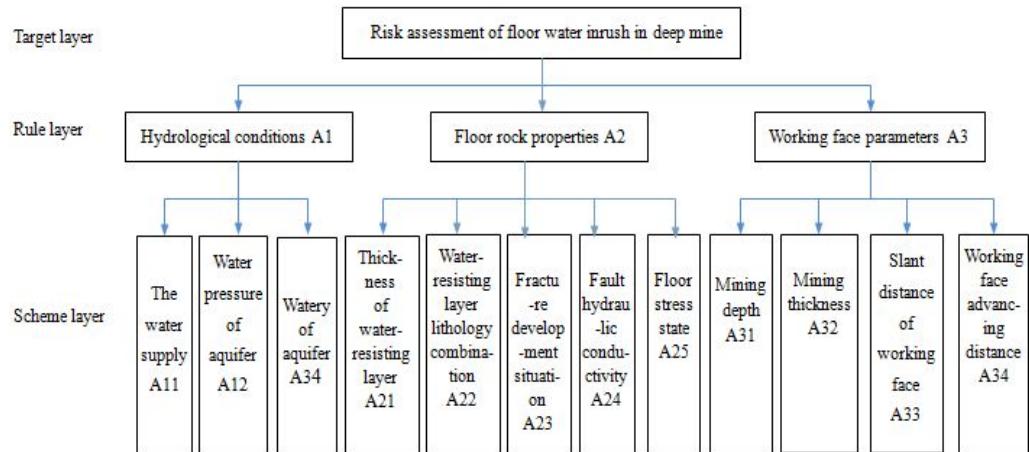


Fig. 1 Hierarchical analysis model of deep mine water inrush risk assessment

Table 1 Total collation of each factor weight

factors	A <sub>1</sub> $\omega=1/3$	A <sub>2</sub> $\omega=4/9$	A <sub>3</sub> $\omega=2/9$	weight	rank
A <sub>11</sub>	5/22	0	0	0.0758	6
A <sub>12</sub>	9/22	0	0	0.1394	1
A <sub>13</sub>	6/22	0	0	0.1182	2
A <sub>21</sub>	0	9/35	0	0.1092	3
A <sub>22</sub>	0	1/7	0	0.0610	9
A <sub>23</sub>	0	1/5	0	0.0737	8
A <sub>24</sub>	0	8/35	0	0.1041	4
A <sub>25</sub>	0	6/35	0	0.0965	5
A <sub>31</sub>	0	0	4/13	0.0752	7
A <sub>32</sub>	0	0	3/13	0.0496	11
A <sub>33</sub>	0	0	7/26	0.0530	10
A <sub>34</sub>	0	0	5/26	0.0444	12

Check the consistency of the above results, the total order inconsistent degree as well as within the scope of the permit,

meet the requirements of consistency. Through the above calculation results

show that water pressure of aquifer, watery of aquifer, thickness of water-resisting layer, fault hydraulic conductivity, mining depth and floor stress state are the six main factors of floor water inrush in deep mine. The sum of the weights of several factors is 0.6426, accounts for 64.26% of all factors. The result is basically consistent with technical data of the query and past research results.

## 2.2 Grey correlation analysis to select main control factors

Take  $X_i = [X_i(1), X_i(2), X_i(3), X_i(4)]$ =[Possibility of water inrush, Cycle strength, Disaster level, Control measures as various influencing factors correlation

intensity index of deep mine's floor water inrush to analysis grey correlation. According to reference [7], the four indexes of specific quantitative calibration as shown in table 2 to 5.

Table 2 Score of the water inrush possibility

Possibility of water inrush	value
Actually impossible	0.1
Extremely impossible	0.2
Can assume that ,but highly impossible	0.5
Less likely	1
Not often, but possible	3
Quite likely	6
Expected completely	10

Table 3 Score of the cycle appearance

Cycle strength	value
Rarely appeared	0.5
Seldom appeared	1
Once a step away from the show	3
Step away from the show many times	6
Show all the time	10

Table 4 Score of control measure

Control measure	value
Prediction measures	1
Emergency measures	3
Without any measures	5

Table 5 Score of the disaster level

Disaster level	value
No harm	1
Minor injuries	3
Seriously injuries	7
One person died	15
Less than five people died	40
More than five people died	100

The parameters of the various influencing factors of floor water inrush in deep mine is composed of four related indexes quantitative score. Reference sequence is

composed of the optimal value of each related indexes. According to the following formula, various factors affecting the correlation can be obtained, as shown in table 6.

$$\xi(n) = \frac{\Delta_{\min} + \rho \Delta_{\max}}{\Delta_i(n) + \rho \Delta_{\max}}, n=1,2,3,4; i=1,2, \dots, n \quad (1)$$

$$\gamma_i = \frac{1}{n} \sum_{k=1}^n \xi_i(k) \quad (2)$$

Table 6 Correlation and sorting of each factor

Influence factors	correlation	sorting
Water pressure of aquifer	0.6456	2
Watery of aquifer	0.6194	1
The degree of water supply	0.8111	9
Thickness of water-resisting layer	0.6700	3
Water-resisting layer lithology combination	0.8333	12
Fracture development situation	0.8310	11
Fault hydraulic conductivity	0.7022	4
Floor stress state	0.7189	5
Mining depth	0.7251	6
Mining thickness	0.8211	10
Slant distance of working face	0.7570	8
Working face advancing distance	0.7444	7

As the results show that water pressure of aquifer, watery of aquifer, thickness of water-resisting layer, fault hydraulic conductivity, mining depth and floor stress state are the main controlling factors of floor water inrush in deep mine. Results are the same by using grey correlation analysis to select the main controlling factors and using the analytic hierarchy process to select the main controlling factors. Therefore, we can conclusion that choose the above six

factors for risk assessment of floor water

### 3. Risk assessment of floor water inrush in deep mine

#### 3.1 Establish a membership function

In order to analysis and evaluation effectively, when we assess the risk of floor water inrush in deep mine, The order of water pressure of aquifer, thickness of water-resisting layer, floor stress state, mining depth , watery of aquifer and fault hydraulic conductivity membership function are as follows:

$$P = \begin{cases} 0 & p \leq 2 MPa \\ \frac{p-2}{8} & 2 MPa \leq p \leq 10 MPa \\ 1 & p \geq 10 MPa \end{cases} \quad (3)$$

Table 7 Watery of aquifer to the water inrush membership function

Water level membership	very poor	poor	general well	very well
0.1	0.3	0.5	0.7	0.9

#### 3.2 Adjust the main controlling factors' weights

Table 9 Main controlling factors adjustment weight

Main controlling factors	water pressure of aquifer	watery of aquifer	thickness of water-resisting layer	fault hydraulic conductivity	floor stress state	mining depth
Initial weights	0.1394	0.1182	0.1092	0.1041	0.0965	0.0752
Adjusting weights	0.2169	0.1839	0.1699	0.1620	0.1502	0.1170

#### 3.3 Assess the risk of floor water inrush in deep mine

This paper selects five main controlling factors' indicators of deep mining actually(Table 10). Taking an example of this engineering sample, explain the process of water inrush risk assessment in deep mine.

inrush in deep mine is applicable.

$$H = \begin{cases} 1 & h \leq 10 m \\ 1 - \frac{h}{90} & 10 m \leq h \leq 100 m \\ 0 & h \geq 100 m \end{cases} \quad (4)$$

$$F = \begin{cases} 0 & t \leq 0.5 \\ \frac{t-0.5}{1.5} & 0.5 \leq t \leq 2 \\ 1 & t \geq 2 \end{cases} \quad (5)$$

$$D = \begin{cases} 0 & d \leq 600m \\ \frac{d-600}{400} & 600m \leq d \leq 1000m \\ 1 & d \geq 1000m \end{cases} \quad (6)$$

Table 8 Fault hydraulic conductivity to the water inrush membership function

Fault hydraulic conductivity membership	very poor	poor	general well	very well
0.1	0.3	0.5	0.7	0.9

The main controlling factors are shown in table 9.

According to correlation degree matter-element matrix, the order of safety degree about these five engineering samples are as follows: sample 2 > sample 5 > sample 4 > sample 3 > sample 1. Sample 1 is the highest relative risk engineering, sample 2 is relatively the highest degree of safety engineering, predicted results are in conformity with the engineering practice. Sample 2 has no water inrush, the biggest water inrush

quantity of sample 5 is  $4.53 \text{ m}^3/\text{min}$ , the biggest water inrush quantity of sample 4

is  $6.3 \text{ m}^3/\text{min}$ , the biggest water inrush quantity of sample 1 is  $30 \text{ m}^3/\text{min}$ .

Table 10 Engineering samples

Main controlling factors Engineering field	water pressure of aquifer /MPa	watery of aquifer	thickness of water-resisting layer /m	fault hydraulic conductivity	floor stress state	mining depth /m
Liang Zhuang51302	10	very well	28	very well	1.9	1000
Xie Zhuang3414	4	well	20	general	2.4	800
Sun Cun41119	7	well	15	very well	2	920
Xia Zhuang1113	8	well	22	well	3	900
Zhao Ge-zhuang2137	10	very well	24	general	2.1	850

According to correlation degree matter-element matrix, the order of safety degree about these five engineering samples are as follows: sample 2 > sample 5 > sample 4 > sample 3 > sample 1. Sample 1 is the highest relative risk engineering, sample 2 is relatively the highest degree of safety engineering, predicted results are in conformity with the engineering practice. Sample 2 has no water inrush, the biggest water inrush quantity of sample 5 is  $4.53 \text{ m}^3/\text{min}$ , the biggest water inrush quantity of sample 4 is  $6.3 \text{ m}^3/\text{min}$ , the biggest water inrush quantity of sample 1 is  $30 \text{ m}^3/\text{min}$ .

### 3.4 Analysis of the risk assessment results of engineering samples

Determining the partition threshold of the risk assessment in deep water inrush based on the engineering application of gray matter element model: while  $k \leq 0.7$ , the risk bursting large-scale or super-huge type water inrush in the coal face, which is the danger zone of floor water inrush in deep mine; while  $0.7 < k \leq 0.9$ , the working face which is a vulnerable area of the floor water inrush in deep mine

occurs small or medium water inrush, which can be changed by improving the safety potential; while  $k \geq 0.9$ , the face is a safe area of the floor water inrush in deep mine.

### 4. Conclusions

(1)Combining the Chromatographic analysis method and gray correlation analysis, it select and validate six controlling factors of the floor water inrush in deep mine, including the water pressure of aquifer, the rich water of aquifer, the thickness of water-resisting layer, fault hydraulic conductivity, mining depth and the stress state of bottom plate, and determine the corresponding weight of each factor, which is more scientific and reliable.

(2)By building membership function of each main controlling factor, and using the gray matter-element model, the risk of floor water inrush in deep mine was evaluated, and compared to the previous established risk assessment or forecasting methods, this risk assessment method with more accurate predictions, easier to use, can achieve dynamic risk assessment

of the floor water inrush in deep mine.

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