

Research Article

Operating Environment Assessment of the Coalface in Underground Coal Mining Based on Analytic Hierarchy Process (AHP) and Matter-Element Theory (MET)

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The environmental evaluation of the coalface in underground mining is of great significance to the safety of production and the health of miners. In order to achieve the objective and accurate evaluation of the operating environment of the coalface, the indexes of temperature, humidity, noise, illuminance, dust, harmful gas, and wind speed are selected to construct the environment evaluation index system, and the operating environment evaluation model of the coalface based on analytic hierarchy process (AHP) and matter-element theory (MET) is established. Firstly, the operation environment classification criterion is established; the environment objects, joint domain, and classical domain matter-element are built; and the correlation function is calculated. Secondly, the comprehensive correlation matrix is calculated and the environmental grade is judged. Finally, from the broad point of view, three measures are proposed to improve the operation environment of the coalface: development of the environmental evaluation index monitoring system, improvement on miners' safety awareness, and formulation of regulations and policies for coal mine operation environment. The research results can provide guidelines for miners, coal mining enterprises, and occupational environmental safety departments.

1. Introduction

In the composition of total reserves of primary energy resources, the proportions of coal, oil and natural gas are 94%, 1.71%, and 4.29%, respectively. The characteristics of natural resources in China are rich in coal, less oil, and lack of gas [1]. Since the establishment of the People's Republic of China, the accumulative total production capacity of coal is about 75 billion tons and the proportion of coal in the structure of primary energy production and consumption in China has been maintained at 70% and 60%, which has provided a reliable energy guarantee for the long-term stable and rapid development of the national economy and society. The status of coal as the main energy source in China is difficult to change in the short term. It is estimated that the

proportion of coal resources in primary energy will remain 55% in 2030 [2, 3]. Coal resources are mainly derived from underground mining in China. Coalface is the production site of coal and is the key area in the coal mine safety management and environmental monitoring, which is characterized with small working space, many mechanical equipment, poor visual environment, and high temperature. The operating environment of coalface is a general designation for microclimate, harmful gas, dust, and noise within the space of coalface, which affect the working comfort, efficiency, and reliability of the system [4]. With the continuous progress of social civilization, people put more and more demands on the operating environment, and it is particularly important to evaluate the operating environment effectively and accurately.

Scholars have made some contributions on the evaluation for the operating environment of coalface. On the one hand, the coalface operating environment resulting from individual indicators was discussed. Li et al. made an assessment on human thermal comfort based on an uncertain measurement theory [5]. Fu et al. studied the respirable dust pollution in coalface [6]. By means of numerical simulation or experimental research, the movement law of dust in the coalface was researched and the specific dust-proof schemes were proposed [7–10]. Jing et al. evaluated the lighting environment in the fully mechanized coalface based on the light environment index method [11]. Park et al. investigated various heat stress indexes and effective temperature and conducted correlation analysis in order to estimate the thermal environment [12]. Krok presented a model for calculations of the temperature field in electric mine motors with a water cooled frame, which was worked out with the use of modified and improved thermal networks developed by the author for determining the temperature distributions in different types of ac machines [13]. Zhao et al. simulated the thermal environment in the heading face based on the turbulence model, which provided a theoretical and technical basis for coal mine ventilation, cooling, heat harm treatment, and prevention [14]. On the other hand, the comprehensive effect of multiple indicators on the operating environment of coalface in underground mining was also explored. Dey and Pal systematically analyzed the influencing factors of the coalface operating environment [15]. Guan et al. evaluated the coalface operating environment based on the Monte Carlo stochastic simulation [16]. Chen et al. built a multifactor coupling intelligent model of safety evaluation on dynamic environment in coalface based on the kernel principal component analysis and least squares support vector machines [17]. Shi et al. point out the importance of heading's operating environment to work's health and established the evaluating model of the operating environment in the headings using the theory of grey interrelated analysis, which provided new theory bases for supervision and evaluation of the operating environment in the headings of mine [18]. Besides, the fuzzy evaluation theory and analytic hierarchy process (AHP) were also used to classify the working face operating environment [19, 20].

In the above research, the evaluation of individual environmental indicators is specific, but because the operating environment is the result of the interaction of multiple indicators, so the comprehensive evaluation of multiple indicators is more objective. But in the comprehensive evaluation of multi-indexes, different evaluation indexes may be in conflict, and matter-element theory (MET) is a powerful tool to solve the problem of contradiction or incompatibility. MET is the theory of using the matter-element model to solve practical problems. Matter-element is a triplet composed of the matter, the characteristics of the matter, and the value of the matter characteristic, which was recorded as $R = (\text{matter}, \text{matter characteristic}, \text{matter characteristic value})$. When solving incompatible problems, only when the matter, the characteristics of the matter, and the value of the matter characteristic are considered at the same time can the prob-

lem be solved. The main content of MET is to quantitatively describe the variability of matters through the correlation function based on the matter-element model and extension set and then transform the incompatible problem into a compatible problem. For example, when the temperature of a coalface is in the temperature range corresponding to the "comfortable" grade, but the humidity is in the humidity range corresponding to the "uncomfortable" grade, the matter-element model can be used to establish the correlation function to solve the comprehensive correlation degree between the coalface operating environment and each comfort grade. And the final evaluation grade of the coalface operating environment should belong to the comfort grade which has the highest comprehensive correlation with it. To determine the weight of the relevant factors is a necessary step to solve the comprehensive correlation degree, and AHP is an effective method to obtain the weight of the relevant factors. In AHP, the weight of each relevant factor was calculated by the judgment matrix. For this reason, firstly, the indexes of temperature, humidity, noise, illuminance, dust, harmful gas, and wind speed are selected. And then, the environment evaluation model of the coalface based on AHP and MET was established, which was applied to N1228 coalface in Huatai colliery. Finally, three countermeasures to improve the operating environment were discussed in a broad sense.

2. Materials and Methods

2.1. Study Area. Huatai colliery is located in the northeast of the Gangcheng District of Laiwu City, Shandong province, China, as shown in Figure 1(a), which is under the administrative jurisdiction of the Gaozhuang subdistrict office. The geographical coordinates of the mining area are $117^{\circ}40'06'' \sim 117^{\circ}45'30''$ in east longitude and $36^{\circ}09'10'' \sim 36^{\circ}12'27''$ in north latitude. In N1228 coalface, the average thickness of coal seam is 4 m, the buried depth is 900 m, and the coalface width is 120 m (Figure 1(b)). The mining method in N1228 coalface is long wall mining. The transverse arrangement of the coal cutter is used in conjunction with the face conveyor and the hydraulic support to form comprehensive mechanized coal mining equipment to complete the coal cutting, coal dropping, and coal loading operation.

2.2. Methods. An environment evaluation model of the coalface based on AHP and MET is established, which the detailed steps are as follows: selecting the operating environment evaluation factors \rightarrow classifying the operation environment grade \rightarrow building the environment objects, joint domain objects and classical field matter-element \rightarrow determining correlation function \rightarrow determining the weights of evaluation factors \rightarrow calculating the comprehensive correlation matrix \rightarrow judging the environment grade.

2.2.1. Selecting the Evaluation Factors. Because of the relatively closed space and small space, the underground coalface of a colliery has a completely different environment from that of the ground. Therefore, from the point of view of the factors directly affecting the operating environment of coalface, this

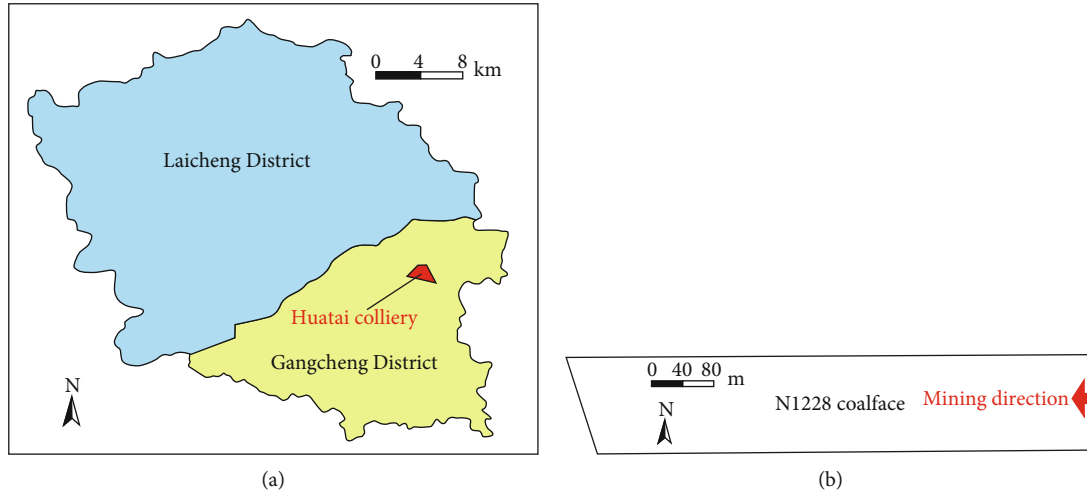


FIGURE 1: Location of the study area: (a) map of Laiwu City and (b) N1228 coalface.

paper selected seven indexes of temperature, humidity, noise, illuminance, dust, harmful gas, and wind speed.

(1) *Temperature*. The main heat sources of the coalface are running mechanical equipment and geothermal energy. At present, with the increasing depth of coal mining, more and more mechanical equipment brought about by development of mechanization leads to more and more heating capacity of mechanical equipment. In addition, the temperature of the exposed rock at the coalface will also increase as the mining depth increases. The above two sources make the thermal hazard of coalface more and more prominent, which has become one of the main factors that affect the safety of coal mine production and the health of the workers.

(2) *Humidity*. Compared with the atmosphere environment, the working face space is closed, and the influence of humidity on the human body is more obvious. When the air humidity is large in the coalface, it can inhibit the evaporation of body heat or accelerate heat conduction, causing the miners to feel uncomfortable. In a worse case, workers work long time in high-humidity areas, which is easy to cause wet arthralgia and seriously affect the health of coal miners.

(3) *Noise*. The noise in the working face mainly comes from mechanical equipment, such as coal cutter, boring machines, and coal conveyer. Noise affects the workers' vascular system, the nervous system, and the digestive system and can cause irreversible damage to the hearing, even affecting the safety of production and operation efficiency.

(4) *Illuminance*. Illumination is the intensity of light and the extent of an object's surface lighted, whose unit is lux or lx [21]. Because of the narrow working space in the coalface, if the illumination is not enough and the visibility is low, it is impossible to detect the running state of vehicles or coal cutter and surrounding environment, so workers cannot take measures in advance, which give rise to accidents. If the long-term illumination is not enough,

the workers work only by the miner's lamp, which can cause blind spot in the visual center of the eye or lose the ability to see objects directly, that is, the so-called mine blind occupational disease. Therefore, illuminance is an important index in the environment evaluation of the coalface in underground mining.

(5) *Dust*. In the working face, dust usually refers to solid particles which are explosive and harmful to people's physical health and form dust hazards when they exist in the form of clouds. The dust comes mainly from the operation process, such as drilling, coal cutting, loading, and blasting. The dust hazards in the coal mining face are as follows. On the one hand, the dust has the risk of explosion at the proper concentration; on the other hand, dust will pollute the operating environment, affect the health of the miners, and lead to pneumoconiosis in miners.

(6) *Harmful Gas*. The harmful gases in the coalface mainly include carbon monoxide (CO), sulfur dioxide (SO₂), and hydrogen sulfide (H₂S). When CO and H₂S are inhaled into the human body, the transport capacity of oxygen in blood or the ability of the tissue to utilize oxygen are impaired, which results in the hypoxia of the tissue. SO₂, a strong irritant gas with colorlessness, acid taste, and well solubility in water, has strong irritation and erosion to the eyes and respiratory tract, which can cause inflammation of the throat and bronchi, respiratory paralysis, and pulmonary edema in severe cases. The safety and hygiene standards in China for the concentration of SO₂, CO, and H₂S are 15 mg/m³, 30 mg/m³, and 10 mg/m³, respectively [22].

The hazard evaluation of a certain harmful gas is measured by index S , where the calculation formula of index S is

$$S = L \cdot \left(\frac{C_i}{M_i} \right), \quad (1)$$

TABLE 1: Evaluation grade of the operating environment in the coalface.

Factor	Evaluation grade				
	More comfortable	Comfortable	Generally comfortable	Less comfortable	Uncomfortable
Temperature (°C)	20-24	24-26	26-28	28-30	30-45
Humidity (%)	40-50	50-60	60-70	70-80	80-100
Noise (dB)	0-70	70-80	80-90	90-100	100-180
Illumination (lx)	120-300	100-120	80-100	60-80	0-60
Dust (mg/m ³)	0-4	4-6	6-8	8-10	10-30
Harmful gas	0-0.5	0.5-1.0	1.0-1.5	1.5-2.0	2.0-5.0
Wind speed (m/s)	3-4	2-3	1-2	0.5-1	0-0.5

where C_i is the concentration of the i th kind gas, mg/m³; M_i is the maximum allowable concentration of the i th kind gas, mg/m³; and L is the weight coefficient of total pulmonary ventilation. When there is a variety of harmful gas, the index of harmful gas can be accumulated.

(7) *Wind Speed*. In order to ensure the health of the coal miners, to provide appropriate production environment, and to improve work efficiency, ventilation must be carried out at the working face of the colliery. The direct measurement index of ventilation is wind speed. The suitable wind speed can effectively cool and dehumidify in the underground working face, but too high or low wind speed also causes worker's discomfort.

In 1228 coalface, the concentration of SO₂, CO, and H₂S are 4.06 mg/m³, 0.43 mg/m³, and 3.35 mg/m³ by site test, respectively. So, the S value of the harmful gas index was calculated based on formula (1), that is, $S = 1.24$. Moreover, the values of noise, humidity, illumination, wind speed, temperature, and dust concentration are 95 dB, 55%, 77 lx, 0.7 m/s, 29°C, and 6.2 mg/m³, respectively.

2.2.2. *Classifying the Operating Environment Grade*. According to the above analysis of environmental factors, from the point of view of human physiological and psychological adaptation to the environment, the operating environment condition of the coalface is divided into 5 grades, that is, more comfortable, comfortable, generally comfortable, less comfortable, and uncomfortable, as shown in Table 1.

2.2.3. *Analysis Procedure of AHP and MET*. The MET, a cross-disciplinary of thinking science, system science, and mathematics science, is an emerging discipline to study and solve incompatible problems, which have been widely used in the field of natural science and social science in decision-making, management, and evaluation [23].

The name of the matter N , the characteristics of the matter c , and the value of the matter characteristic v are determined, and $R = (N, c, v)$ is used as the basic element to describe the object, which is called matter-element.

A thing has more than one feature, if the object N has n characteristics, such as c_1, c_2, \dots, c_n , and corresponding

values v_1, v_2, \dots, v_n are described, which can be represented as

$$R(N, c, v) = \begin{bmatrix} N & c_1 & v_1 \\ & c_2 & v_2 \\ & \vdots & \vdots \\ & c_n & v_n \end{bmatrix}, \quad (2)$$

where R is an n -dimensional matter-element, c_i is the matter-element characteristics, and v_i is the value of the matter characteristic.

The operating environment of the coalface is evaluated based on MET, and the steps are as follows:

(1) *Determining the Environment Objects*. According to the actual situation, to evaluate the characteristics of a certain object, the measured values of multiple characteristics are determined and the corresponding matter-element matrix is established, as shown in

$$R_0(P_0, c, v) = \begin{bmatrix} P_0 & c_1 & v_1 \\ & c_2 & v_2 \\ & \vdots & \vdots \\ & c_n & v_n \end{bmatrix}, \quad (3)$$

where P_0 is the environment objects, c_i is matter-element characteristics, and v_i is the measured value of the matter characteristic.

(2) *Determining Classical Field and Joint Domain Mater-Element*. The classical field and joint domain mater-element are determined by the operating environment grade, as shown in

$$R_j(N_j, c, v_{ji}) = \begin{bmatrix} N_j & c_1 & v_{j1} \\ & c_2 & v_{j2} \\ & \vdots & \vdots \\ & c_n & v_{jn} \end{bmatrix} = \begin{bmatrix} N_j & c_1 & \langle a_{j1}, b_{j1} \rangle \\ & c_2 & \langle a_{j2}, b_{j2} \rangle \\ & \vdots & \vdots \\ & c_n & \langle a_{jn}, b_{jn} \rangle \end{bmatrix}, \quad (4)$$

$$R_p(N, c, v_{pi}) = \begin{bmatrix} N_p & c_1 & v_{p1} \\ & c_2 & v_{p2} \\ & \vdots & \vdots \\ & c_n & v_{pn} \end{bmatrix} = \begin{bmatrix} N_p & c_1 & \langle a_{p1}, b_{p1} \rangle \\ & c_2 & \langle a_{p2}, b_{p2} \rangle \\ & \vdots & \vdots \\ & c_n & \langle a_{pn}, b_{pn} \rangle \end{bmatrix}. \quad (5)$$

(3) *Determining Correlation Function.* The correlation function indicates that when the value of the matter-element characteristic is taken as a point on the real axis, the matter-element meets the required range of values, and the value is the correlation degree. The correlation degree $K_j(v_i)$ (v_i) of each evaluation index v_i about each evaluation grade j is expressed as formula (6).

$$K_j(v_i) = \begin{cases} -\frac{\rho(v_i, v_{ji})}{|a_{ji} - b_{ji}|}, & v_i \in v_{ji} \\ \frac{\rho(v_i, v_{ji})}{\rho(v_i, v_{pi}) - \rho(v_i, v_{ji})}, & v_i \notin v_{ji} \end{cases}, \quad (6)$$

where $\rho(v_i, v_{ji}) = |v_i - ((a_{ji} + b_{ji})/2)| - ((b_{ji} - a_{ji})/2) =$

$$\begin{cases} a_{ji} - v_i, & v_i \leq (a_{ji} + b_{ji})/2 \\ v_i - b_{ji}, & v_i > (a_{ji} + b_{ji})/2 \end{cases},$$

$$\rho(v_i, v_{pi}) = \left| v_i - \frac{(a_{pi} + b_{pi})}{2} \right| - \frac{(b_{pi} - a_{pi})}{2} = \begin{cases} a_{pi} - v_i, & v_i \leq \frac{(a_{pi} + b_{pi})}{2}, \\ v_i - b_{pi}, & v_i > \frac{(a_{pi} + b_{pi})}{2}. \end{cases} \quad (7)$$

(4) *Determining the Weights of Evaluation Factors.* AHP is an analytic procedure with a combination of qualitative and quantitative, systematic, and hierarchical analyses. The weight of each factor of the operating environment is determined using AHP, and the steps are as follows:

- (1) Building the structure model of AHP

The structure of AHP is shown in Figure 2.

- (2) Constructing judgment matrix and calculating eigenvalues and eigenvectors

The judgment matrix is constructed based on the Saaty's 1 ~ 9 scale scoring method [24] (Table 2), and eigenvalues and eigenvectors are calculated.

- (3) Check the consistency of the judgment matrix

Firstly, consistency index CI is calculated, $CI = (\lambda_{\max} - n)/(n - 1)$. Secondly, the corresponding average random

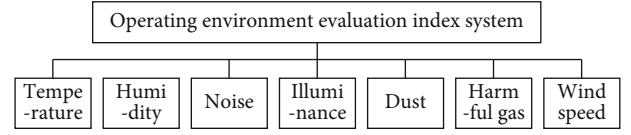


FIGURE 2: Structure model of AHP

TABLE 2: Scale meaning from 1 to 9.

Scale	Meaning
1	Equal importance
3	Weak importance
5	Obvious importance
7	Strong importance
9	Absolute importance
2, 4, 6, 8	Represents the intermediate value of the adjacent judgment
Reciprocal	If element i /element $j = a_{ij}$, then if element j /element $i = 1/a_{ij}$

TABLE 3: Values of average random consistency index RI.

Order	3	4	5	6	7	8	9	10
RI	0.52	0.89	1.12	1.26	1.36	1.41	1.46	1.49

consistency index RI is referred in Table 3. Thirdly, consistency ratio CR is calculated, $CR = CI/RI$. When $CR < 0.1$, the consistency of the judgment matrix is acceptable; otherwise, the judgment matrix is modified.

If the judgment matrix satisfies the consistency test requirement, the normalized eigenvector of the judgment matrix is the weight of each index factor.

(5) *Calculating the comprehensive correlation degree.* The comprehensive correlation degree $K_j(P_0)$ is the weighted value of the correlation degree $K_j(v_i)$ of each evaluation index v_i about each evaluation grade j , which is shown in formula (8)

$$K_j(P_0) = \sum_{i=0}^n w_i \cdot K_j(v_i), \quad (8)$$

where w_i is the weight of factors and $K_j(P_0)$ is the comprehensive correlation degree.

(6) *Judging the environment grade.* K_j is used to judge the environment grade, as shown in formula (9)

$$K_j = \max \{K_j(P_0)\}. \quad (9)$$

It is concluded that the corresponding grade of the maximum value of the comprehensive correlation degree is the grade of the environment objects.

$$R_j(N_j, c, v_{ji}) = \begin{bmatrix} & N_1 & N_2 & N_3 & N_4 & N_5 \\ c_1 & \langle 20, 24 \rangle & \langle 24, 26 \rangle & \langle 26, 28 \rangle & \langle 28, 30 \rangle & \langle 30, 45 \rangle \\ c_2 & \langle 40, 50 \rangle & \langle 50, 60 \rangle & \langle 60, 70 \rangle & \langle 70, 80 \rangle & \langle 80, 100 \rangle \\ c_3 & \langle 0, 70 \rangle & \langle 70, 80 \rangle & \langle 80, 90 \rangle & \langle 90, 100 \rangle & \langle 100, 180 \rangle \\ c_4 & \langle 120, 300 \rangle & \langle 100, 120 \rangle & \langle 80, 100 \rangle & \langle 60, 80 \rangle & \langle 0, 60 \rangle \\ c_5 & \langle 0, 4 \rangle & \langle 4, 6 \rangle & \langle 6, 8 \rangle & \langle 8, 10 \rangle & \langle 10, 30 \rangle \\ c_6 & \langle 0, 0.5 \rangle & \langle 0.5, 1.0 \rangle & \langle 1.0, 1.5 \rangle & \langle 1.5, 2.0 \rangle & \langle 2.0, 5.0 \rangle \\ c_7 & \langle 3, 4 \rangle & \langle 2, 3 \rangle & \langle 1, 2 \rangle & \langle 0.5, 1 \rangle & \langle 0, 0.5 \rangle \end{bmatrix}. \quad (10)$$

The joint domain objects and the environment objects mater-element are shown in matrixes (11) and (12), respectively.

$$R_p(N, c, v_{pi}) = \begin{bmatrix} N_p & c_1 & \langle 20, 45 \rangle \\ & c_2 & \langle 40, 100 \rangle \\ & c_3 & \langle 0, 180 \rangle \\ & c_4 & \langle 0, 300 \rangle \\ & c_5 & \langle 0, 30 \rangle \\ & c_6 & \langle 0, 5 \rangle \\ & c_7 & \langle 0, 4 \rangle \end{bmatrix}, \quad (11)$$

$$R_0(P_0, c, v) = \begin{bmatrix} P_0 & c_1 & 29 \\ & c_2 & 55 \\ & c_3 & 95 \\ & c_4 & 77 \\ & c_5 & 6.2 \\ & c_6 & 1.24 \\ & c_7 & 0.7 \end{bmatrix}. \quad (12)$$

3.2. Correlation Degree Matrix. The correlation degree matrix of each evaluation index about each environment grade is as shown in

3. Results

3.1. Classical Field Mater-Element, Joint Domain Objects, and Environment Objects. The classical field mater-element of the operating environment is shown in

$$K_j(v_i)_{7 \times 5} = \begin{bmatrix} 0.5 & 1.5 & 1.25 & -0.5 & 0.0667 \\ 0.5 & -0.5 & 0.5 & 1.5 & 1.25 \\ 0.5 & 1.5 & 0.3571 & -0.5 & 0.0625 \\ 0.15 & 1.15 & 0.2389 & -0.15 & 0.2833 \\ -0.1 & 0.1 & 0.55 & 0.9 & 0.19 \\ -0.48 & 0.48 & 1.48 & 0.52 & 0.2533 \\ 0.3 & 1.3 & 2.3 & -0.4 & 0.4 \end{bmatrix}. \quad (13)$$

3.3. Index Weight. The weights of the operating environment evaluation factors are determined using AHP, as shown in Table 4.

3.4. Comprehensive Correlation Vector and Environment Grade. According to the correlation degree matrix (13) and index weight indexes, the comprehensive correlation vector is calculated using formula (8), as shown in

$$K_j(P_0)_{1 \times 5} = [-0.0218 \quad 0.7581 \quad 1.172 \quad 0.2291 \quad 0.3023]. \quad (14)$$

It is concluded that the operating environment grade of N1228 coalface in Huatai colliery is “generally comfortable.”

4. Discussion

4.1. Development of Environmental Evaluation Index Monitoring System. In Table 4, the weight of the harmful gas is the greatest. Harmful gas is the most important

TABLE 4: Index weight.

Index	Temperature	Humidity	Noise	Illuminance	Dust	Harmful gas	Wind speed
Weight	0.1194	0.0649	0.0554	0.1398	0.0929	0.3996	0.1281
Rank	4	6	7	2	5	1	3

indicator to the operating environment of the working face, which poses a great threat to the safety of miners' lives. Coalface will continue to advance with coal mining or tunneling activities, and the thickness and dip angle of the coal seam will change or geological structure will appear in the process of advancing, which have the potential to cause impact on the concentration of harmful gases. For this reason, it is necessary to develop a set of reasonable mine environmental monitoring system to monitor the changes in environmental indicators in working face and to protect the health and safety of miners, which can collect and alarm the environment parameter and image data with system stability and short transmission delay.

4.2. Improvement on Miners' Safety Awareness. Safety consciousness is a kind of advanced psychological reflection form of safety production or environment state people have, which can reflect people's understanding of the safety or the environment state in the production activity [25]. Human's safety consciousness has active nature, which regulates production activities and safety operations; conversely, production activities also affect the formation of people's safety consciousness. It is necessary to raise the safety consciousness of miners and ensure the safety of production and the health of miners. Therefore, four methods for improvement on the safety consciousness of miners are put forward.

4.2.1. Raising Workers' Recruitment Requirements. First of all, all candidates are screened by age, educational background, physical examination, and cultural examination, and then, an open reply was made for those who are not allowed to be employed without meeting the standards, which not only solves the problem of low overall quality of workers but also reflects the recruitment of employees open and fair. Secondly, an off-the-job training is made for new workers who can be called formal workers after passing the examination.

4.2.2. Educational Training. Educational training is the key to improve staff safety awareness. In combination with the actual situation of workers, the training of knowledge at different levels and division of labor is adopted. For workers who have different levels of knowledge, the educational level and technical knowledge of workers are divided into three categories: good, medium, and poor, which bring about the difference of the contents and methods of training. Division of labor training refers to the separate training of different types of jobs, and training should have professional characteristics.

4.2.3. Carrying Out Warning Education. Warning education can further improve the effectiveness of safety education training, allowing workers to learn a lot of security experience and strengthen self-protection awareness. There are

many ways of warning education, such as the previous coal mine accidents being made into cartoons and posted on the safety bulletin board.

4.3. Formulation of Regulations for Coal Mine Operation Environment. According to the Safety Production Law of People's Republic of China, the Coal Law of People's Republic of China, the Coal Mine Safety Law of People's Republic of China, the Law of People's Republic of China on Prevention and Control of Occupational Diseases, and other relevant laws and regulations, the environmental monitoring regulations of the coal mine working face should have been further formulated, and the environmental level of the working face is divided. In addition, the responsibility of the operation environment is implemented to the individual to ensure the safety of the mine production and the health of the miners. What is more, regulations also need to stipulate that the training time for employees is not less than 10 hours before the job induction, and the regular training time is not less than 5 hours per year during the postperiod.

5. Conclusions

In order to ensure the safety of coal mine safety production and the health of miners, the evaluation method was put forward based on AHP-MET, and the operating environment of N1228 coalface was evaluated. Conclusions are as follows:

- (1) The indexes of temperature, humidity, noise, illuminance, dust, harmful gas, and wind speed are selected, and the environment evaluation index system is constructed
- (2) The operating environment evaluation model of the coalface based on AHP and MET is established, which was applied to evaluate the operating environment of the N1228 coalface
- (3) From the broad point of view, three measures are proposed to improve the operation environment of the coalface: development of environmental evaluation index monitoring system, improvement on miners' safety awareness, and formulation of regulations and policies for coal mine operation environment

Data Availability

All data used during the study and appearing in the submitted article are available from the corresponding author upon request.

Conflicts of Interest

The authors declare that there is no conflict of interest regarding the publication of this paper.

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