Evaluation of Mine Geo-environment Quality in Shangnan Country Based on Information Weight Method and Set Pair Analysis

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Abstract. Mining development is the pillar industry of the Shangnancounty andfrequent mine activities is the primary reason that leads to geo-environment problems. As the number of mine is large and poor concentration, taking Shangnan country as the research area. Evaluation index system is built that contains the influence of mining development on geo-environment, basic geology and ecological environment, a total of 15 indexes. Dividing the study area into 169 square units which length is 4km and using information weight method to calculate the weight of evaluation index. Then, the connection degree of each unit will be obtained by set pair analysis. Finally, according to connection degree intervals, mine geo-environment quality levelscan be devided into "serious", "general" and "good". The result shows: ①spatial distribution of mine geo-environment quality in Shangnan county is quite different; ②the quality of mine geo-environment in the central and northern of Shangnan county are obviously superior to that in the south; ③the "serious", "general" and "good" each occupies 8.28%, 53.85% and 37.87% of research area. The result can provide theoretical basis for mine geo-environment comprehensive management of Shangnan County.

1. Introduction

Shangnan country is rich in mineral resources. There are 103 mines and 32 different kinds of mineral resources, among which has the biggest reserve of rutile in Asia and the specularite is the second largest in the world. By the end of 2017, there are 183 geological hazards in Shangnan country, including 178 landslides, 4 collapses and 1 debris flow. In order to definite problems area and guide the treatment of mine geo-environment, it's essential to research the mine geo-environment quality and analyzes spatial distribution characteristics [1-3]. At present, the quality evaluations of mine geo-environment in China are mostly centered on single mine and the comprehensive evaluation of geo-environment quality of regional mines is still under exploration [4-5]. The paper takes Shangnan country as the research area and focus on the universality of evaluation indexes. It can be used as the reference for regional mine geo-environment quality evaluation.

2. Mining development and the spatial distribution of geo-environment problems

At present, the main developed minerals in study area are navajoite, iron ore, marble, rutile, albite, barite and concentrate on Qingshan town, Shuigou town, Weijiatai town, Shiliping town that lies in the central and south mountainous areas.Collapses, landslides, debris flows are the main geological hazards.According to the statistics, there are 115 geological hazards in Weijiatai town, Shuigoug town, Qingshan town, Xianghe town and Shiliping town, which occupies 63% of the county. The distribution of mines and geological hazards instudy area are shown in figure1. It's easy to find that they have a good consistency in spatial distribution.

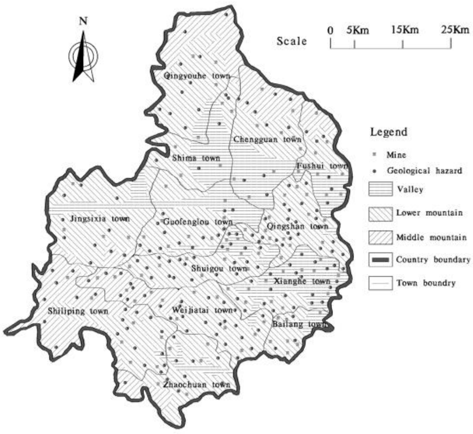

Figure 1. The distribution map of mines and geological hazards in study area

3. Evaluation index system and evaluation method

3.1. Evaluation index system

3.1.1 Building evaluation index system. Evaluation index system is the basis and critical part of the evaluation. Proper index system will have a profound impact on the evaluation [6-8]. Based on the evaluation index systems in Ningxia, Shandong, Gansu and Jilin, and the principles of pertinence, conciseness, quantification and easy to obtain [9]. Three aspects, 15 indexes are selected that come from the influence of mining development on geo-environment, basic geology and ecological environment. As shown in table1.

Table 1. Evaluation index system of mine geo-environment quality

Target	Criterions	Attributes
Evaluation of mine ge-environment quality(A1)	Influence of mining development on geo-environment(B1)	Mine types (C1)
		Mine amount (C2)
		Mine scale (C3)
		Recovery method (C4)
		Solid waste accumulation/10^4t (C5)
		Waste water discharge/10^4t (C6)
		Occupied land area/hm^2(C7)
		Cause losses /10^4 yuan (C8)
	Basic geology(B2)	Terrain (C9)
		Distance from regional fault/km (C10)
		Numbers of geological hazards (C11)
	Ecological environment(B3)	Density of population /persons·km^{-2} (C12)
		Damage rate of terrain landscape/% (C13)
		Classification of groundwater quality (C14)
		Vegetation bestrewing rate/% (C15)

3.1.2 Evaluation index classification. Because of the uncertain indexes, mine geo-environment is a complex system. In order to make a quantitative and accurate evaluation, we using the fuzzy to classify the evaluation indexes in terms of table2. Based on "investigation of mine geo-environment assessment standard"(DD2014-5), "detailed investigation report of mine geo-environment in Shangnan county", "statistical yearbooks" and "statistics bulletin on national economy and social development of Shangnan county", the indexes can be classified into five grades, as shown in table2.

Table 2. Table of evaluation indexes classification assignment

Assignment	Better(4)	Good(3)	Ordinary(2)	Worse(1)
Mine types	Building materials mine	Nonmetal mines (non building materials)	Metal mine	Energy mine
Mine amount	≤2	(2, 4]	(4, 6]	>6
Mine scale	Small	Middle	Large	Enormous
Recovery method	Underground mining		Opencast mining	
Solidwaste accumulation/10^4t	≤1	(1, 4]	(4, 7]	>7
Waste water discharge/10^4t	≤0.5	(0.5, 3]	(3, 5.5]	>5.5
Occupied land area/hm^2	≤1	(1, 6]	(6, 10]	>10
Cause losses/10^4 yuan	≤10	(10, 30]	(30, 50]	>50
Terrain	Valley	Hilly	Lower mountain	Middle mountain
Distance from regional fault/km	≥20	(10,20)	(5, 10]	≤ 5
Numbers of geological hazards	≤3	(3, 6]	(6, 9]	>9
Density of population /persons·km^{-2}	≤100	(100, 300]	(300, 500]	>500
Damage rate of terrain landscape/%	≤10	(10, 20]	(20, 40]	>40
Classification of groundwater quality	Ⅰ	Ⅱ	Ⅲ	Ⅳand below
Vegetation bestrewing rate/%	≥30	(20,30]	(10, 20]	≤ 10

3.2. Evaluation method

The study area can be divided into 4km*4km evaluation units by square mesh division method that amount is 169.As shown in figure 2. Firstly, assigning values to each unit through table 2. Then calculating the weight by information weight method. Thirdly, using set pair analysis to achieve the connection degree of each unit. Finally, dividing the quality levels of mine geo-environmentby their connection degrees.

Information weight method determines weight based on the quantity of information in index data. It is an objective method, which can avoid the interference of human factors and make a realistic evaluation[10-12].Compared with the subjective weighting method, the weights that calculated by objective method are based on the actual investigation data. It will not be explained again, as it has the merits of simple principle, convenient calculation and mature application in scientific researches [13]. Set pair analysis is gradually infiltrating in relevant fields of scientific research. It is suitable to evaluate the quality of mine geo-environment, for its ability of dealing with deterministic or uncertain systems that consisted of random, blurry and incomplete factors [14].

IOP Conf. Series: Materials Science and Engineering **381** (2018) 012010 doi:10.1088/1757-899X/381/1/012010

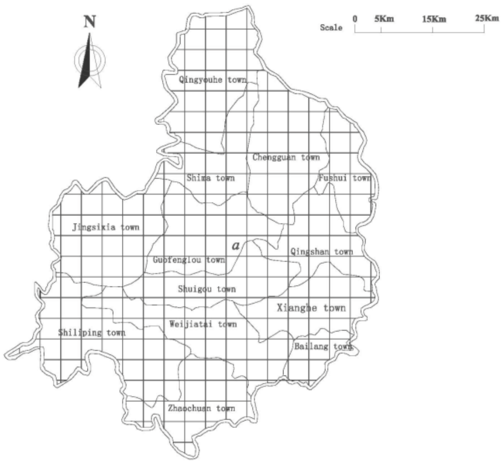

Figure 2. Grid map of evaluation units in research area

Set pair analysis is a method that combines two sets into a set pair that related to each other. It believed that the characteristics of two sets can be divided into three directions: the same, the different and the opposite, it can be expressed in terms of the connection degree, as shown in equation (1).

$$u = \frac{S}{N} + \frac{F}{N} \bullet i + \frac{P}{N} \bullet j \tag{1}$$

In equation (1): u is the connection degree of set pair; N is the sum of characteristics; S is the same characteristics that exist in two sets. P is the number of opposing characteristics of two sets; $F=N-S-P$ represents the characteristics of two sets that different from each other. i is the difference coefficient of uncertainty and its scope is [-1, 1], 1 or -1 is certainty, $i \in (-1, 1)$ is uncertain and the uncertainty increases obviously when i approach to 0; j is the opposite coefficient, it's value usually takes -1.

Equation (1) can be expressed in equation (2), while considering the weight of each index

$$u = \sum_{k=1}^{S} w_k + \sum_{k=S+1}^{S+F} w_k \bullet i + \sum_{k=S+F+1}^{N} w_k \bullet j \tag{2}$$

In equation (2): W_k(k= 1,2,3...,N) is the weight of indexes that obtained by the information weight method; the concept of i and j is the same as the equation (1).In order to calculate the connection degree conveniently, equation (2) can be rewritten as equation (3) and use Matlab to realize rapid calculation.

$$\begin{aligned} u &= W \times R \bullet E \\ &= [w_1 \quad w_2 \quad w_3] \times \begin{bmatrix} a_1 & b_1 & c_1 \\ a_2 & b_2 & c_2 \\ \cdots & \cdots & \cdots \\ a_k & b_k & c_k \end{bmatrix} \bullet \begin{bmatrix} 1 \\ i \\ j \end{bmatrix} \end{aligned} \tag{3}$$

In equation (3): W is the weight coefficient vector; R is an measurement evaluation matrix of identical, and inverse multivariate; E is the matrix of contact component. The relation degrees of the evaluation units can be achieved by equation (3).

4. Mine geo-environment quality partition

As mentioned above, the research area is divided into 169 squre evaluation units. Taking evaluation unit "*a*" in Guofenglou town as an example, then describe the calculation process of its connection degree, the other units could be dealt with as the same way. Each index weight of unit "*a*" in Guofenglou town is calculated by information weight method.

According to equation (3) and the weight of each index in table3, the connection degree of the evaluation unit "*a*" is calculated as shown in equation (4).

$$\begin{aligned} u &= W \times R \bullet E \\ &= [0.61 \quad 0.17 \quad 0.22] \times \begin{bmatrix} 1 & 0 & 0 \\ 0.63 & 0.37 & 0 \\ 0.6 & 0 & 0.4 \end{bmatrix} \bullet \begin{bmatrix} 1 \\ i \\ j \end{bmatrix} \\ &= 0.839 + 0.063i + 0.088j \end{aligned} \tag{4}$$

Table 3. Indexes weights of evaluation unit "*a*"

Criterions	Weights	Attributes	Weights
B1	0.61	C1	0.06
		C2	0.08
		C3	0.04
		C4	0.11
		C5	0.12
		C6	0.07
		C7	0.05
		C8	0.08
B2	0.17	C9	0.04
		C10	0.07
		C11	0.06
B3	0.22	C12	0.04
		C13	0.08
		C14	0.04
		C15	0.06

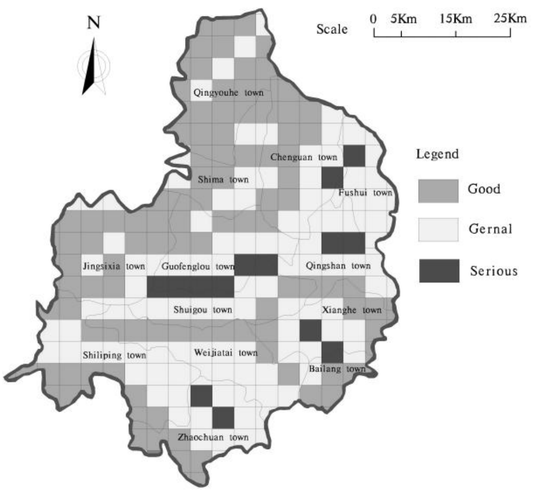

Figure 3. Classification map of mine geo-environment quality in research area

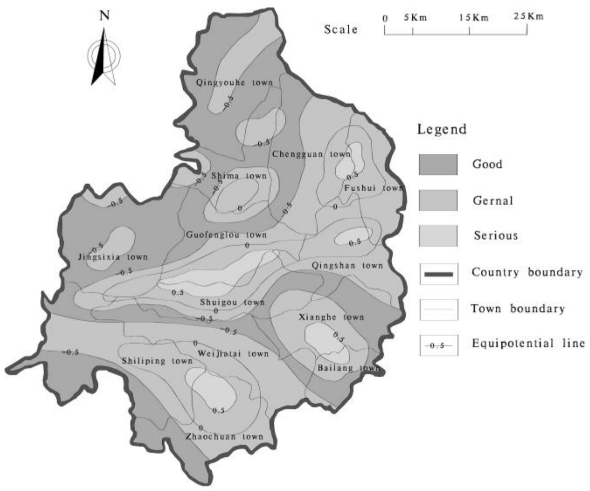

Figure 4. Equipotential line map of mine geo-environment quality in study area

The elements of *R* and values of *i* can be obtained through the reference [15]. After the calculation, we find the range of connection degrees is [-1,1]. Using the defined interval method to divide the range into [-1, -0.5), [-0.5, 0.5) and [0.5, 1], respectively corresponding to the "good", "general" and "serious". For the evaluation unit "*a*”, no matter the value of *i* how to change in [1, 1], connection degree scope is [0.688, 0.814], the intervals of [0.5, 1]. So the mine geo-environment quality grade of unit "*a*" is "serious". Based on the above measures, achieving connection degrees of remaining 195 evaluation units and dividing them into "serious", "general" and "good". The classification map of mine geo-environment quality can be obtained by Mapgis6.7, as shown in figure 3. In order to exhibit the difference of mine geo-environment quality of different regions in study area quantitatively, the equipotential line map of mine geo-environment quality is drawn with the central coordinate and connection degree of each unit. As shown in figure 4.

5. Discussion

Among the 169 evaluation units, fourteen units are classified as "serious", ninety-one units as "general" and sixty-four as "good". Combined with the detailed investigation report of mine geo-environment in research area and figure 1, 3, 4.It can be seen that:

The geo-environment quality level is "serious", which mainly distribute on the mountainous area of shangnan county, accounting for 8.28% of the research area. There are a lot of mines that mined underground. Main geo-environment problems are the geological hazards and water-soil pollution that caused by mining development. The volume of slag is $113.62*10^4m^3$, and covers an area of $83.87hm^2$.

The geo-environment quality level is the "general" are mainly distribute on the south and east of research area, accounting for 53.85% of Shangnan county. There are a little mines and the mineral oreis limestone. Primary geo-environment problems are land occupation and vegetation destruction.

The geo-environment quality level is the "good" mainly distribute on the west and northeast of shangnan county, accounting for 37.87% of the study area. There are few mines and the impact of mining development on geo-environment is relatively slight.

6. Conclusion

The mining activities are very important for the operation and development of mining cities. Minegeo-environment quality evaluation is an essential part of mine geo-environment comprehensive treatment. The evaluation index system is based on the impact of mining development on geo-environment, taking the basic geology and ecological environment into account, a total of 3 categories and 15 indexes. The evaluation index system has the advantages of strong pertinence, comprehensive analysis, easy calculation and understanding.

The research area is divided into 169 evaluation units with square mesh division method. Fuzzy mathematics, information weight method and set pair analysis are used to analyze the data. According to the range of connection degree, geo-environment quality levels of study area can be classified as "serious", "general" and "good" and each occupies 8.28%, 53.85% and 37.87% of research area. Evaluation result can provide theoretical basis for mine geo-environment comprehensive management of Shangnan county.

7. Acknowledgments

The research was supported by National Natural Science Foundation of China (Grant No. 41572287) and Science & Technology Co-ordination and Innovation Projection of Shaanxi Province (Grant No. 2016KTCL03-19).

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