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Article

Evaluation and Countermeasures of Green Mine Construction in Yongcheng City Based on DPSIR Model

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Abstract: Strategic researches on green mine construction are of great theoretical and practical significance to the sustainable development of China's mining industry as well as the great-leap-forward development strategies of China. Strategies of green mine construction in China are methods summarized to solve all potential problems from mine production to ecological restoration. At present, strategies of green mine construction in China are not fully evaluated and studied yet. Therefore, on the basis of green mine construction related literatures carried out by researchers in China and abroad, this study took the green mine of Yongcheng City in China as the research object to evaluate the current situation of green mine construction in Yongcheng and put forward corresponding countermeasures. Firstly, driving force-pressure-state-impact-response model was introduced for the construction of evaluation index system; construction principles and selection methods of indexes and the index system based on driving force, pressure, state, impact and response were constructed. Secondly, principal component analysis was adopted to calculate and evaluate data of green mine of Yongcheng in recent years, and construction state of green mine in Yongcheng was analyzed concretely according to the evaluation results. Empirical results showed that, the evaluation system constructed in this study was feasible, which could be applied to evaluate construction of green mine effectively.

Keywords: DPSIR model; green mine; principal component analysis

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1. Introduction

Since the reform and opening-up, mineral resources have provided China's industrialization and urbanization with lots of important raw materials, which are the basis of rapid social and economical development of China. With the rapid development of social economy, mineral resources will continuously promote social development as the powerful support for industry and other infrastructures. However, in past few decades, the demanded quantity of mineral resources in China has been increasing linearly [1-2]; moreover, due to the lack of comprehensive, systematical and scientific planning and management as well as a strict assessment and supervision mechanism, resource exploitation and utilization in mineral industry shows an extensive growth mode [3]. However, the most worrying problem in recent years is the environmental pollution caused by mine exploitation. After the coal production increased for continuous 14 years, it showed a decreasing tendency in 2014 for the first time, which was due to the decrease of market demand [4-5] and much more than this, constraint of environmental policies [6]. Therefore, the contradiction among resource,

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society and environment is the key problem that constraints the development of mine enterprises as well as the sustainable development of mine industry in China.

At present, China is faced with the social and economical transformation, accompanying with the continuously increasing resource and energy demand as well as the aggravation of resource and environment pressure. Therefore, we have to reconstitute development and utilization of mine resources from a strategic height to realize the comprehensive harmonious and sustainable development of economy, society and environment [7]. Traditional mine exploitation method is featured by high investment, high consumption, high pollution and low profit [8]. Green mine construction aims at scientific development and efficient utilization of mine resources, energy conservation and emission reduction, environmental protection and community harmony, as well as takes scientific exploitation, efficient resource utilization, standardization of business management, environmental friendly manufacturing techniques and ecologicalization of mining area environment as requirements; moreover, green mine construction aims to change development modes radically to realize the comprehensive and sustainable development of resource benefit, environmental benefit, economic benefit and social benefit. Therefore, taking the Yongcheng mining area as the research object, this study analyzed evaluation model and countermeasures of green mine construction based on driving force-pressure-state-impact-response (DPSIR) model.

2. CONSTRUCTION OF DPSIR MODEL

2.1. DPSIR MODEL FRAMEWORK

DPSIR model is a hierarchical theoretical framework constituted of target layer, criterion layer and index layer. Letters of DPSIR represent drive force, pressure, state, impact and response, respectively [9-10].Five parameters in DPSIR model can comprehensively describe the causal relationship in environmental system changes [11]. Drive force refers to basic influencing factors that cause natural resource and environment changes, such as population, economical development status, environmental conditions and natural resources, etc. Pressure refers to various kinds of factors produced by influencing factors of drive force, which can cause pressure to natural resources and environment; compared with the drive force, these factors can cause more direct influence on natural resources and environment. State refers to a kind of state under pressure, which is closely related to the evaluated target. Impact refers to the results produced by combined action of the former three parameters, including impact of natural resources and environment and maybe other social economic factors. Response refers to some kind of measures adopted according to relevant index state in state and impact to optimize the current state, such as policy measures and legal means, etc.Five parameters of DPSIR model have close causality. All links in the interaction between human and natural system can be expressed as a circulatory system by causality. Selected indexes are involved in all aspects of resource and environment system; the analyzed causality is comprehensive and objective; qualitative information can be quantified using the model and better mathematical methods can be selected to obtain results that are more visualized and easier to be evaluated.

2.2. CONSTRUCTION OF EVALUATION INDEX SYSTEM

2.2.1. Construction principle

The evaluation system of green mine construction has complex structure and involves lots of indexes. Excessive indexes can result in redundancy and logical mass, which will influence evaluation results and increase evaluation difficulty; however, too few indexes are not sufficient for comprehensive and accurate evaluation of green mine construction. Therefore, when it comes to practical evaluation, typical indexes which can objectively and comprehensively reflect construction situation of green mine should be selected according to nine basic requirements of green mine accreditation as well as certain index selection and construction principles. On the basis of characteristics of the index system of green mine construction, principle of integration of universality and characteristics as well as the

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binding character and selectivity should be followed, other than general principles like scientificity, dynamics, comprehensiveness and feasibility.

2.2.2. Framework of evaluation index system

DPSIR model is a hierarchical theoretical model. Evaluation based on DPSIR model should firstly define the content of each layer of the model. According to the basic framework of model, the model contains three layers which are target layer, criterion layer and index layer. The target layer refers to evaluating construction situation of green mine taking the construction level of green mine as the general objective; criterion layer includes five indexes which are drive force, pressure, state, impact and response, indicating the effect of each system on the overall system of green mine construction; index layer contains further detailed evaluation indexes according to contents of criterion layer, including various specific indexes, and the index layer is the minimum unit in index system. Selection of evaluation indexes of the criterion layer is crucial to the construction of the whole system, thus evaluation indexes should be screened out scientifically (figure 1).

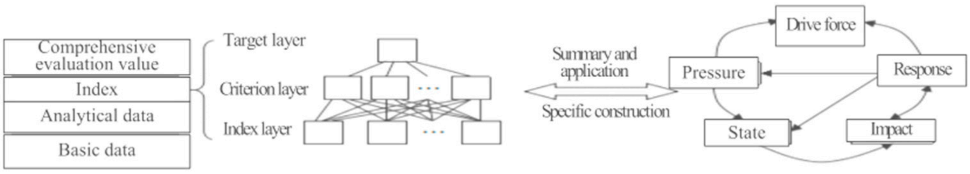

Figure 1. Framework of DPSIR model

According to foregoing contents, this study includes both qualitative indexes and quantitative indexes, and most basic indexes have different properties and units, which are difficult to be measured by unified standards. Therefore, all index data should be translated into unified non-dimensional data before determination of index weight.Figure 1 shows that, suppose there are m index layers and each index layer has n evaluation indexes; then initial data matrix can be formed according to iAitial data.

$$z_{ij} = \frac{x_{ij} - \overline{x}_j}{S_j} \quad i = 1,2,\cdots,m;\ \mathrm{m} = 1,2,\cdots,n;\ m \in (0,3], n \in (0,6]$$

In the above equation,◎ $\overline{x_j} = \left(\sum_{i=1}^{m} x_{ij}\right)$ and $s_j^2 = \sum_{i=1}^{m}\left(x_{ij} - \overline{x_j}\right)^2 / (m-1)$ .Besides, z_{ij} refers to the standardized data of the jth index value of the ith index layer; x_{ij} is the initial index value; x_j is the average value of selected samples; S_j refers to the sample standard deviation.

This study also involves some qualitative indexes, such as public satisfaction index and implement of policies and regulations; quantification processing should be carried out first before evaluation of these two indexes and values can be determined by expert scoring method; the scoring results can be divided into three categories: excellent (10 points), good (8 points) and average (6 points).

2.2.3. Applicability examination

Before principal component analysis (PCA), all initial data should be given applicability examination to examine the correlation among variables of initial data, thus to determine whether selected samples are suitable for PCA or not. Bartlett sphericity test and Kaiser-Meyer-Olkin (KMO) test are usually used for PCA [12-13]. KMO test was selected in this study. KMO test is mainly used to express the relative size of simple correlation coefficient and partial correlation coefficient among different indexes. The value interval of KMO is [0, 1]; when the value of KMO is approaching 1, it indicates that the correlation among all indexes is strong and the selected sample is appropriate for PCA; otherwise, the selected sample is inappropriate for PCA. Table 1 shows the measurement standards of KMO.

Table 1 Measurement standards of KMO

Value interval of KMO	**[1,0.9]**	**(0.9,0.8]**	**(0.8,0.7]**	**(0.7,0.6]**	**(0.6,0.5]**	**(0.5,0]**
Applicability	Extremely suitable	Very suitable	Average	Basically suitable	Unsuitable	Quite

2.3. PRINCIPAL COMPONENT ANALYSIS

If all initial data pass KMO test, selected samples will be given PCA. Initial data matrix after standardization is $Z=(Z_{ij})_{m\times n}$; sample data after standardization are used to calculate correlation coefficients; then characteristic values and relevant feature vectors are obtained.

2.3.1 Algorithm of correlation coefficient matrix

Suppose the correlation coefficient matrix of standardized sample is:

$$R=(r_{jk})_{n\times n},\ r_{jk}=\frac{1}{m-n}\sum_{i=1}^{m} z_{ij} z_{jk}\ ;\ j=1,2,\cdots,n\ ;\ k=1,2,\cdots,n$$

In the equation, r_{ij} refers to the correlation coefficient of index j and index k.

2.3.2 Algorithms of characteristic root and feature vector

n characteristic roots $\lambda_p(p=1,2,\cdots,n)$ and feature vectors $U_p=(u_{1p},u_{2p},\cdots,u_{np})$ can be obtained by characteristic equation $|R-\lambda_i E|=0$. Characteristic root λ_p in descending order can be expressed as $\lambda_1\geq\lambda_2\geq\cdots\geq\lambda_n\geq 0$.

2.3.3 Determination of the principle component and its number

A group of characteristic roots obtained by above method is the variance of principle components, indicating the effect of each principle component when describing evaluated objects; then according to the principle that the variance contribution should be bigger than 85%, principle components are extracted and recorded as Y. Expression of the principle component of the ith sample is $Y_p=U_P^T Z$,which is the first principle component; Y2 is the second principle component; similarly, Yn is the nth principle component.

PCA is to reduce the number of initial indexes under the circumstance that the amount of information loss is the least. Suppose the number of principle components is p and p<n, then variance contribution is:

$$a(p)=\frac{\lambda_p}{\sum_{p=1}^{n}\lambda_p},\ a(p)\geq 85\%$$

After the determination of linear weighted value of principle components, weighted values of every principle component should be summed. Therefore, the comprehensive evaluation value F of green mine construction is:

$$F = \sum_{p=1}^{n} a(p) Y_p$$

3. EVALUATION OF GREEN MINE CONSTRUCTION

3.1 STATUS OF MINING AREA CONSTRUCTION IN YONGCHENG CITY

The mining area of Yongcheng City belongs to the coal-bearing region in North China in late paleozoic era; its coal-bearing stratum is permo-Carboniferous system, which belongs to platform-type coal-bearing deposit in North China. So far 25 layers of coal seams were discovered, including 7 layers of minable seams and partially minable seams; average thickness of main minable seams is 1.36~2.84 m; burial depth of coal seams is 225~1000 m. In recent years, mining area construction in Yongcheng City has received good achievements, as shown in table 2.

Table 2. Implementation completion degree of coalmine production work of Yongcheng City and planning control indexes in recent four years

Index		2012	2013	2014	2015
Environmental protection and land rehabilitation	Green coverage ratio of mining area in	20%	24%	34%	46%
	Land rehabilitation ratio in recoverable	26%	31%	46%	48%
	Restoration and control ratio of mine environment in recoverable areas	31%	42%	48%	79%
Comprehensive utilization	Use ratio of solid wastes	48%	61%	71%	91%
	Reuse rate of mine waste water	78%	82%	83%	91%
	Recovery ratio of working face mining	92%	93%	95%	97%
	Comprehensive utilization ratio of mineral	34%	46%	51%	58%
Community harmony and enterprise culture	Million working hour injury ratio	2.02%	1.22%	0.96%	0.23%
	Times of safety production training(/month/person)	1	2	3	4

3.2 EVALUATION OF GREEN MINE CONSTRUCTION

3.2.1 Standardization of initial data

According to characteristics of green mine of Yongcheng City, 20 basic indexes were selected, involving economy, policy, laws and regulations, mining industry and environment, etc. Collected data received standardization processing, as shown in table 3.

Table 3. Standardized data of mine indexes of Yongcheng City

Target	System	Influencing factor		Index layer	2012	2013	2014	2015
Comprehensive index of green mine construction level (F)	Drive force system (D)	Economic growth	D1	Output per manshift	-0.691	0.497	0.659	0.938
			D2	Per capita income	-0.375	1.135	1.324	2.836
	Pressure system (P)	Pollutant emission	P1	Emission load of smoke	0.418	-0.122	-0.756	-1.620
			P2	Emission load of SO2	0.550	0.047	-0.912	-1.431
		Resource consumption	P3	Energy consumption of unit	0.698	-0.066	-0.923	-0.994
			P4	Water consumption of unit	1.278	-0.362	-0.868	-0.883
	State system (S)	Ecological environment	S1	Use ratio of coal gangue	-0.160	-0.158	0.913	0.913
			S2	Reuse ratio of coal-washing	-0.191	0.285	0.774	0.770
			S3	Use ratio of mine water	-0.727	-0.343	0.302	1.606
			S4	Comprehensive use ratio of	0.090	0.553	0.556	0.551
		Production technology	S5	Recovery ratio of mining	0.172	-0.351	0.937	0.782
			S6	Ore dressing recovery	0.055	0.254	0.384	0.986
	Impact system (I)	Social impact	I1	Public satisfaction	-0.457	-0.303	0.655	1.335
			I2	Staff morbidity	1.258	0.009	-1.271	-1.723
	Response system (R)	Enterprise investment	R1	Proportion of scientific and technological innovation fund	1.130	-0.582	0.235	1.608
			R2	Proportion of environmental protection input in mine	-0.836	0.392	0.041	0.937
		Environmental governance	R3	Green coverage ratio in mining area	-0.726	0.009	0.839	1.514
			R4	Land rehabilitation ratio in mining area	-0.735	-0.295	0.757	1.311
			R5	Restoration and control ratio of mine environment	-0.425	0.084	0.684	1.513
		Standardized management	R6	Implementation of laws and regulations	-0.443	-0.448	1.045	1.042

KMO test of above standardized sample data showed that, the KMO value was 0.610 which was bigger than 0.6, indicating that the data were appropriate for PCA.

3.2.2 Determination of principle components

Table 4 shows that, characteristic root, variance contribution rate and accumulated variance contribution rate obtained by calculation of 20 initial data were all higher than 90%, except for the variance contribution rates of the first three initial data (D_1 , D_2 and P_1). Variance contribution rates of the first three initial data were 56.156%, 26.314% and 5.421%, respectively; accumulated variance contribution rate reached 87.891%. Therefore, according to the principle that variance contribution rate should be higher than 85%, above three principle components could be extracted.

Table 4. Total variance contribution of green mine construction

Component	Initial eigenvalue			Loaded values of extracted quadratic sum		
	Summatio	Contribution rate	Accumulated	Summation	Contribution rate (%)	Accumulated
1(D1)	13.296	56.156	56.155	13.296	56.128	56.127
2(D2)	5.986	26.314	82.472	4.986	21.714	77.843
3(P1)	1.277	5.421	87.892	1.177	6.427	84.267

3.2.3 Calculation of principle component value

After that, principle component matrix was extracted. Principle component load matrix reflected the contribution rate of each principle component to its corresponding initial index (table 5). Values in the principle component load matrix represented the correlation coefficients of indexes to principle components [14-16]. The variance contribution of the first principal component Y_1 was 56.156%, indicating that most indexes of green mine construction of Yongcheng City focused on Y_1 ; moreover, index loads of D_1 , D_2 , P_3 , P_4 , S_3 , S_6 and R_3 in Y_1 were big, which were 0.945, 0.931, 0.952, 0.929, 0.925 and 0.956, respectively, indicating that Y_1 could comprehensively reflect the economic benefit, resource utilization and environmental protection, etc. Variance contribution of the second principal component Y_2 was 26.314%, which showed certain information explanatory capability to green mine construction. Table 5 shows that, indexes like P_1 , P_2 and I_2 in Y_2 had high load, which were 0.915, 0.619 and 0.732, respectively, indicating problems of resource utilization and safety production. Variance contribution of the third principal component Y_3 was 5.421%, which showed weak explanatory capability to green mine construction; the load of land rehabilitation ratio in Y_3 was high, reflecting the environmental restoration and treatment.

Table 5 Principle component load matrix of green mine construction

Influencing factors	Principle component			Influencing factors	Principle component		
	1	2	3		1	2	3
D_1	0.945	0.163	-0.235	S_5	0.893	-0.178	0.297
D_2	0.931	-0.164	0.294	S_6	0.925	0.283	-0.046
P_1	-0.196	0.915	-0.042	I_1	0.436	-0.785	0.395
P_2	-0.355	0.619	-0.105	I_2	-0.554	0.732	-0.084
P_3	-0.952	0.058	0.148	R_1	0.776	0.492	0.345
P_4	-0.824	0.188	-0.513	R_2	0.728	-0.253	-0.363
S_1	0.831	0.113	0.518	R_3	0.956	0.168	-0.176
S_2	0.875	0.404	-0.223	R_4	-0.032	-0.284	0.476
S_3	0.929	0.333	-0.007	R_5	0.603	-0.201	0.046
S_4	0.798	0.324	0.092	R_6	0.754	0.452	-0.084

Expression of principle component can be obtained according to $Y_p = U_P^T Z$;in addition, according to a(p)and F , comprehensive evaluation values of green mine construction of Yongcheng City can be calculated: $F = 0.5616Y_1 + 0.2633Y_2 + 0.0544Y_3$

On the basis of above formula and standardized data, comprehensive evaluation values of green mine construction of Yongcheng City from 2012 to 2015 could be obtained, as shown in table 6.

Table 6. Comprehensive evaluation values of green mine construction of Yongcheng City

	Y_1	Y_2	Y_3	F
2012	-6.128	2.160	-2.879	-2.872
2013	1.472	-0.743	0.601	0.601
2014	10.857	-1.605	5.739	5.740
2015	18.362	-2.653	9.728	9.727

Table 6 shows that, F value of coalmine in Yongcheng City from 2012 to 2015 increased steadily; Y_1 also increased at a fast speed. Y_1 values from 2012 to 2015 were lower than 0 and analysis of initial data indicated that the ore dressing recovery percentage was lower than 75%. From 2012 to 2015, multiple indexes showed good development tendency; S_5 and S_6 reached or even surpassed national standards; P_3 and P4 decreased slightly; meanwhile, R_3 and R_5 increased significantly, thus the comprehensive construction level of mine in Yongcheng City in aspects, such as resource utilization, environmental governance and management ability, etc., also improved.

From 2012-2015, Y_2 decreased slowly. The main influencing factor of Y_2 was negative index, thus Y_2 was bigger than 0 before 2013; after 2013, Y_2 was less than 0, indicating that the environmental

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pollution and safety problem of mining area of Yongcheng City were serious before 2013 and improved after 2013. Explanatory ability of Y_3 to initial index information was weak, thus Y_3 was not analyzed in this study.

4. Discussion

During green mine construction, Yongcheng City experienced the transformation from extensive management mode of high energy consumption, high pollution and ecological damage to green mining method of low carbon, energy saving and environmental protection; informationalized mine was constructed basically and connectivity of inside and outside the mine was realized by integration of mine industry and information technology, thus to effectively guarantee safety of constructors; moreover, circulation economy development pattern was further expanded and secondary processing and utilization of wastes of coal gangue, coal slime and coal ash was realized; in addition, industry chain of circular economy that had Yongcheng City characteristics was formed, energy waste and waste emission were minimized by technical energy saving and harmony of economical development and ecological environment was realized. However, some early problems left over by history, such as environmental pollution, gangue accumulation and sunk land, etc., were not solved completely, which hindered the further development of green mine construction.

4.1. Scientific planning of green mine construction

Overall planning of development, utilization and construction of mine resource as well as economic development and environment protection of Yongcheng City should be carried out according to national policies and practical conditions of the mining area; resource mining, dressing and smelting, land rehabilitation [17], ecological reconstruction and environmental governance should be well planned, and corresponding management mechanism and measures should be constructed to guarantee the comprehensive utilization of resources and development of circular economy.

4.2. Promotion of digitalization and informatization in mining areas

The key of green mine construction is technology-driven. Technology in the future will develop in accelerated speed and update cycle of technology and equipment will be shortening constantly. Therefore, medium and long-term green construction can be achieved only the technological innovative ability and independent research and development ability are improved and scientific and technological achievements are transformed to real productivity. Informatization construction of coalmine, mechanization of mining system, improvement of system automation, continuity of coal flow transportation and informatization of monitoring system [18] should be promoted; equipment automation and modern management level should be improved by upgrade and update.

4.3. Implementation of responsibility system and mining management

Mining area of Yongcheng City should form a management mechanism system that has its own characteristics based on experience of advanced enterprises in China and abroad. Meanwhile, management network system should be constructed; clear-cut division of labor and responsibility assessment should be guaranteed, thus to truly implement the mechanism as well as fully improve standardizing management of enterprises.

4.4. Recycling economy development mode

The traditional "resource-production-pollution-emission" mode and "treatment after pollution" end treatment method [19] should be abandoned, and the recycling economy development mode which sticks to "optimal production, consumption-oriented and minimum waste" should be followed to [20]. Moreover, the core ideology of green mine development should be "reduction, harmless and recycling", which emphasizes green production and sustainable development of green mine.

5. Conclusions

The mining areas in Yongcheng City were taken as an example in this study. On the basis of development status and characteristics of mining areas of Yongcheng City, appropriate countermeasures or suggestions were put forward for green mine construction of Yongcheng City. DPSIR model was introduced in this study; evaluation index system of green mine construction in Yongcheng City was constructed based on five system influencing factors and their interaction; then PCA was adopted to determine index weight and load by index standardization and principle component extraction; finally comprehensive evaluation values were calculated. Although DPSIR evaluation model of green mine is constructed, there are still many problems need further improvement and upplement.

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