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Research on Early-Warning Method and its Application of Complex System of Circular Economy for Oil and Gas Exploitation

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Abstract

It is a very important link to determine the reference in the warning of circular economy development, because it's the key to ensure the accuracy of warning result. To establish reference not only have to consider the convenience of data calculation, but also have to consider patterns of economic exploitation complied with the principle of circular economy when choosing criterion-referenced indexes. Only in this way can we ensure the warning results as accurate as possible, give timely warning to the exploitation methods which can't meet the circular economy and guide the formulation of regulatory policies.

In this paper, on the basis of operational early-warning Indexes system of complex system of circular economy for oil and gas exploitation, early-warning method with fuzzy ISODATA cluster analysis has been established. Furthmore, decision analysis of warning outcome has been analyzed, which is combined with practice of LN oil field of T Company. The author believes that the fuzzy ISODATA cluster analysis based early warning system and decision analysis would be practicability.

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Keywords: early-warning;fuzzy ISODATA cluster analysis;circular economy;oil and gas exploitation

1. Introduction

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The core of the circular economy is to achieve renewable or recycled resources; the fundamental goal is to avoid and reduce waste in the economy systematic process, while achieving rapid and healthy economic growth. The construction of oil and gas circular economy complex system early warning system is significant for scientific evaluation of the development of circular economy in oil and gas industry and advancing the development of circular economy in oil and gas industry, that is, providing a basis for management decisions, monitoring and exposing social conflicts and social problems in the process of economic and social development, analyzing the causes of conflicts and problems and giving the information to resource management department in time, promoting regional sustainable development.

This article is organized as follows: In the next section, we analyze Early-Warning Indexes System of Complex System of Circular Economy for Oil and Gas Exploitation In the third section, Early-Warning method based on fuzzy ISODATA cluster analysis is applied in circular economy complex system. Furthermore, decision analysis is described. And in the final section, we conclude by discussing the model with a case study.

2. Early-Warning Indexes System of Complex System of Circular Economy for Oil and Gas Exploitation

2.1. Construction Principle

Therefore, we based on the following principles to select early-warning indexes system, comprehensive and briefly reflect current situation and development potential of circular economy of exploitation of oil and gas, including “3R”Principle, systematic principle guiding principle, comparability principle, operational principle and regional principle.

2.2. Basic framework and the selection of indexes

2.2.1. General framework

The early warning indexes of circular economy of exploitation of oil and gas system are standards and scales of evaluating circular economy of exploitation of oil and gas construction and development goals. As we establish the early warning structure of circular economy of exploitation of oil and gas system, on the one hand, it should be based on all the existing statistical system and information; on the other hand, it's organic synthesis, extraction, sublimation and a certain degree of innovation on the statistical indexes of traditional economic, environmental and social areas.

2.2.2. Selection of indexes

（1）Hierarchical structure of indexes system

The early warning system of circular economy of exploitation of oil and gas system with sub-level as warning unit can make warning analysis of 4 sub-systems; then make a comprehensive warning on the basis; finally make the final decision analysis to maintain sustainable development of circular economy complex system.

1) Target level (A): Target level is the overall goal of the entire system. We use sustainable level of complex system of circular economy of exploitation of oil and gas to measure.

2) Criteria level (B): we use it to evaluate sustainable level of complex system of circular economy of exploitation of oil and gas.

① Degree of economic development coordination (B1): reflects sustainable coordination degree of exploitation of oil and gas economy system.

② Degree of social coordination (B2): reflects the social support system and framework structure in the development of the regional cycle oil and gas exploitation.

③ Environmental Sustainability (B3): reflects the environment protection of the regional cycle oil and gas exploitation development and construction characteristics of the environment.

④ Resource Sustainability (B4): reflects the status of regional resources, status of development and management and conditions of ecological protection and resume building.

3) Index level (C & D)

Index level consists of the indexes under sub-index level of criterion level, which including four indexes: economic subsystem index, social subsystem index, resources subsystem index and ecological environment index.

（2）Operational warning indexes system

Operational early warning indexes system (as shown in Table.1.) is more emphasis on the statistical standards interface of safety and environmental protection department with oil and gas Exploitation Company. It is mainly from the perspective of four subsystems which based on circular economy "three" guiding principles for the evaluation of regional circular economy. By establishing the link with social progress, ecological environment[1] and resources planning and management, development of regional circular economy can be overall measured and achieve win-win situation.

3. Warning method of complex system of circular economy of exploitation of oil and gas

3.1. Principles of fuzzy ISODATA cluster analysis [2,3]

When n samples that form L set are divided into class m by the application of fuzzy set theory, we can think that sample l_j is subject to i at a certain membership grade All samples belong to each class by different membership grade. At this point, the corresponding classification matrix $U_f = (u_{ij})_{m*n}$ should meet the following conditions, is given by Eq(1):

① $u_{ij} \in [0,1], \forall i, j$; u_{ij} denote sample l_j, subject to membership grade of i ;

$$\text{②}\ \sum_{i=1}^{m} u_{ij} = 1, \forall j \quad ; \qquad \text{③}\ \sum_{i=1}^{m} u_{ij} > 0, \forall j \quad . \tag{1}$$

Each matrix U_f that meets these three conditions corresponds to a fuzzy classification and all the fuzzy classification matrix form the fuzzy classification space,is given by Eq(2) :

$$M_{fm} = \left\{ U_f \middle| u_{ij} \in [0,1], \sum_{i=1}^{m} u_{ij} = 1, \sum_{i=1}^{m} u_{ij} > 0, \forall i, j \right\} \tag{2}$$

In order to obtain optimal classification, the objective function as Eq.(3) given by :

$$J(U_f, V) = \sum_{i=1}^{m} \sum_{j=1}^{n} u_{ij} \parallel L_j - V_i \parallel^2 \tag{3}$$

The results should be minimized. On this basis, in order to change the relative membership degree of the sample flexibly, the objective function should be changed as Eq.(4) given by:

$$J_p(U_f, V) = \sum_{i=1}^{m}\sum_{j=1}^{n}(u_{ij})^p \parallel L_j - V_i \parallel^2 \quad (4)$$

Table 1. Operational early warning indexes system of complex system of circular economy on oil and gas exploitation

Target level (general indexes)	Criteria level (indexes of warning situation)	Project level (warning indexes)	Index level (warning source indexes)	
Sustainability of complex system of circular economy on oil and gas exploitation(A)	degree of economic development coordination (B1)	indexes of ecological economic benefits	renewable resources yield	
		indexes of Circular economy	coverage rate of industrial recycling network	
		function indexes of circular economy	reduction indexes	clean water consumption coefficient
				material scrap coefficient
			reuse and resources indexes	drilling fluid circulation rate b
				crude oil circulation rate c
				wastewater circulation rated
			harmless indexes	the attainment rate of wastewater
				the attainment rate of waste gas
				the attainment rate of solid waste
	degree of social coordination (B2)	structural frame indexes	non-material services promotion rate	
		functional mechanism indexes	efficiency of circular economic and social regulation mechanism	
	degree of ecological and environmental sustainability (B3)	environmental quality indexes	air quality	
			ratio of groundwater up to water quality standards in water function area	
		ecological protection and construction indexes	the proportion of environmental protection investment in the total industrial output value	
	degree of resources sustainability (B4)	resource depletion and scarcity indexes	The ratio of scarce resources	
		rational use and ecological damage control indexes	the proportion of ecologically sensitive areas	
			utilization rate of scarce resources development and control	
		Resource management, rehabilitation and construction indexes	implementation rate of resource use and plan	

[1] drilling fluid circulation rate: In normal drilling conditions (excluding lost circulation and other non-normal conditions), the proportion of drilling fluid circulation in the total of drilling fluid,(the sum of supplement and circulation) in the process of the same drilling.
drilling fluid circulation rate(%)=drilling fluid/(supplement of drilling fluid＋drilling fluid circulation)×100%
[2] recovery of landing crude oil
landing crude oil: crude oil which is off the ground directly with on protective measures.
landing crude oil circulation rate(%)=landing crude oil recovery / landing crude oil production×100%
[3] wastewater circulation rate(%)=wastewater recycling/wastewater production×100%

p is the parameter that will be selected. When given $p=2$, the formula is given by as follows:

$$J_2(U_f,V)=\sum_{i=1}^{m}\sum_{j=1}^{n}(u_{ij})^2\,\|L_j-V_i\|^2 \quad =\sum_{i=1}^{m}\sum_{j=1}^{n}(u_{ij}\,\|L_j-V_i\|)^2 \tag{5}$$

Defining $u_{ij}\,\|Lj-V_i\|$ as the generalized distance between sample ι_j and class ι, $J_2(U_f,V)$ reflects quadratic sum of generalized distance between all samples and each class and has a clear physical concept. If other value is given to p, the physical concept will be unclear. Subjective element will also increase in actual use.

The classification results may be numerous when we do fuzzy classification for samples. In order to obtain optimal classification, we need to find the corresponding classification matrix u_f^* and cluster centers V^* which make the objective function $J_p(U_f,V)$ minimize, the formula is given by Eq(6):

$$J_p(U_f^*,V^*)=\min\{J_p(U_f,V)\} \tag{6}$$

Generally, it's very difficult to solve above problems directly. However, when $p>1>,L_j\neq V$, The following formula can be used for iteration as follows:

$$V_1=\frac{\sum_{j=|}^{n}(u_{ij})^p L_j}{\sum_{}^{n}(u_{ij})^p},\forall i \tag{7}$$

$$u_v=\frac{1}{\sum_{k=1|}^{m}\left(\frac{\|L_j-V_i\|}{\|L_j-V_k}\right)^{\frac{2}{p-1}}},\forall i,j \tag{8}$$

3.2. Steps of fuzzy ISODATA cluster analysis

When we use fuzzy ISODATA cluster analysis to classify the samples, we should follow these steps:

① Choose an initial classification matrix U_f (membership degree of all samples can't be exactly the same) and set iterative precision $\varepsilon>0$;

② Use Eq(7) to calculate V^*;

③ Use Eq(8) to calculate u_f^*;

④ If $\max\limits_{\substack{1\le i\le m\\1\le j\le n}}\{|u_{ij}^*-u_{ij}|\}<\varepsilon,$, u_f^* and V^* is the answer, otherwise return to Step (2) and continue to iterate until satisfied.

3.3. Verify of classification results

Classification result by using fuzzy ISODATA cluster analysis is the optimum solution with respect to class m, initial classification matrix U_f, error ε and parameter p. If we change m, U_f, ε and p, we will get a lot of partial optimum solution. Thus we need to test the classification results by using the following indexes:

① Classification coefficient, is given by Eq(9) :

$$F(U)=\frac{1}{n}\sum_{j=|}^{n}\sum_{i=|}^{m}u_{ij}{}^{2} \tag{9}$$

② The average fuzzy entropy, is given by Eq(10) :

$$H(U)=-\frac{1}{n}\sum_{j=|}^{n}\sum_{i=|}^{m}u_{ij}\cdot\ln(u_{ij}) \tag{10}$$

Where: the more $F(U)$ close to 1, the more $H(U)$ close to 0, and the better of classification.

Table .2. Warning degree and situation of complex system of circular economy on oil and gas exploitation

Warning degree		No warning	Micro warning	Middle warning	Heavy warning	Violent warning
Warning grade		1	2	3	4	5
light		blue	water blue	green	yellow	red
warning situation	economic subsystem	economic exploitation patterns are in full compliance with the principles of circular economy	economic exploitation patterns are in compliance with the principles of circular economy	economic exploitation patterns are basically compliance with the principles of circular economy	economic exploitation patterns are partly compliance with the principles of circular economy	economic exploitation patterns contrary to the principles of circular economy
	social subsystem	support effectively for management and adjustment of complex system operation of circular economy	support well for management and adjustment of complex system operation of circular economy	support for management and adjustment of complex system operation of circular economy	support relatively poor for management and adjustment of complex system operation of circular economy	support poor for managemen t and adjustment of complex system operation of circular economy
	ecological resources subsystem	ecological resources security is good	ecological resources security is relatively good	ecological resources security is ordinary	ecological resources security is relatively poor	ecological resources security is poor
	resources system	resources utilization is economical, pollution emissions is small and the degree of recycling is high	resources utilization is relatively economical, pollution emissions is relatively small and the degree of recycling is relatively high	resources utilization is ordinary, pollution emissions is ordinary and the degree of recycling is ordinary	resources utilization is low, pollution emissions is high and the degree of recycling is low	resources utilization is high, pollution emissions is high and the degree of recycling is high

3.4. Decision analysis of warning of complex system of circular economy on oil and gas exploitation

Identification of warning degree is to identify the warning degree range of warning variable on circle economy. Complex system warning of circular economy on oil and gas exploitation is based on the sustainable comprehensive indexes of economic subsystem system, social subsystem system, resources subsystem system and ecological environment system. Therefore, combining with expert advice, warning degree were divided into 5 degrees as follow: no warning, micro warning, middle warning, heavy warning and violent warning, which can be represented by blue light, water blue light, green light, yellow light and red light. Accordingly, warning of circular economy and the corresponding warning were shown in Table .2.

When the signal is blue, it indicates that the complex system of circular economy on oil and gas exploitation is at a steady stage with ability of risk resistance. We should continue to follow the direction of sustainable exploitation; when the signal is green, it indicates that oil and gas exploitation might be affected by internal and external uncertain factors which may cause the risk. We should prepare for the risk; when the signal is yellow, it indicates that most indexes values are abnormal. We must prevent potential risks by adjusting the way of resource exploitation, implementing appropriate management control measures and strengthening environmental protection and resource management; when the signal is red, it indicates that most indexes are seriously deviate from normal values, resistance capacity of complex system of circular economy on oil and gas exploitation is poor. It faces enormous risk. At this point, we should reformulate and deploy new exploitation modes of circle economy; otherwise, it will bring irreparable loss to resources and the environment.

3.5. Example

The goal of pilot projects of circular economy on oil and gas exploitation is to make guidelines of improving the environment and production operation management and reducing pollution emissions. In this project, LN oil field of T Company is selected as demonstration areas by China National Petroleum Corporation. LN oil field is one of several major oil-producing regions of T Company, which consists of three production areas, LN1, LN2 and LN3. LN1 operation area is the main production area. Crude oil which is exploded in LN oil field is sent to number 5 central processing stations for processing. LN oil field has 5 test separator, 159 wells, 3 gathering stations and a central processing station. Since 1989 LN oil field has been explored and developed.

According to internal regulations of T Company, the quality safety and environmental protection department would conduct a regular check for 3 operation areas of LN oil field every month in order to strengthen the management of LN circular economy system. Considering of the desirability of data, the warning time of this case is that we selected the results that we checked LN1 operation area between early in 2007 and end in 2010 as sample to establish warning model. Therefore, data from 36 groups in LN1 work area of T Company were selected as basic data.

After standardized factors of samples and fixed their weight, we make warning analysis with data that from LN1 operation of LN oil field of T Company by ISODATA fuzzy cluster analysis. According to the number of obtained samples (36), the results were shown in Fig.1. and Table.3. The samples were divided into 4 categories. The classification coefficient was 0.9643 and the average fuzzy entropy is 0, so it achieved good classification. From Table.3., we can see the clustering results of samples were divided into 4 different types of warning degree.

Under the early warning system analysis, circular economy system of oil and gas exploitation in LN1 operation area of LN oil and gas field basically lies in no warning state from sample 1 to sample; Circular economy system of oil and gas exploitation in LN1 operation area of LN oil and gas field basically lies in middle warning and weak warning states from sample 9 to sample 20; in major warning state from sample

21 and sample 29. After implementing the corresponding warning measures, the system lies in weak warning and no warning system from sample 22 to 28 and sample 30 to 36.

Table .3. Comparing classification of cluster analysis with the actual classification

type	classification results	warning degree	light	fuzzy clustering	five-category classification
first	1,2,3,5,6,8,15,20,24,30,34,35	no warning	blue	12	12
second	4,7,9,10,11,12,13,16,17,25,26,27,28,31,33	micro warning	water blue	15	13
third	14,18,19,22,23,32,36	middle warning	green	7	5
forth	21,29	heavy warning	yellow	2	2

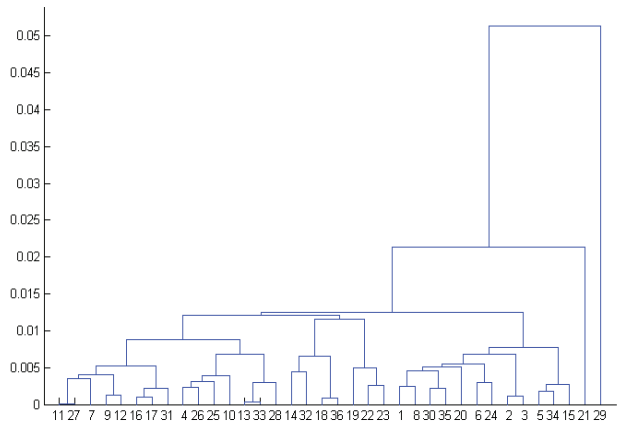

Fig.1. Cluster Tree

Generally speaking, in the premise of a better general trend, the development of circular economy system of oil and gas exploitation in LN1 operation area with the increase of oil and gas exploitation still faces certain risks.

4. Conclusion

It improves better through scientific management, but the aspect of resource security still exist some problems. Since the current economic growth of T Company is still a foreign-style economy, we must ensure economic development while reduce pollution emissions and ensure a harmonious development of economy and environment from the perspective of long-term sustainable development. Meanwhile, because of the depletion of natural resources, the exploitation of resources must be planned; otherwise it will lead to the increase of security warning degree of resources for the future.

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