Level Evaluation of Ecological Sustainable Development of Chemical Enterprises

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Abstract. The report of the CPC National Congress proposed the construction of ecological civilization is a millennial plan for the national development of China, and construction of ecological civilization and ecological protection have therefore been raised to an unprecedented strategic height. With regard to the chemical industry, as a major pillar industry of economic development of China, its consumption of natural resources, and the increasing environmental pollution and destruction, have severely restricted the level of ecological sustainable development of the industry. This article selects the main factors and indicators that affect the ecological sustainable development of the chemical industry, determines the weight of each index through the analytic hierarchy process, and evaluates the level of sustainable development of ecological environment of a chemical enterprise using a fuzzy evaluation method. The results show that the sustainable development level of the enterprise is "average", indicating that the importance of the enterprise in ecological and environmental protection and pollution control still needs to be improved. Enterprises should realize that under the premise of the pursuit of maximum economic efficiency, it is necessary to promote a green economy and clean production and to establish the "effective, stable, economic" whole process optimization pollution control technology, and only in this way, can the sustainable development of enterprises and even the industry and society be ensured.

1. Overview of pollution and ecological sustainable development in the chemical industry

After the reform and opening up, the economy of China has seen a rapid development, the chemical industry has also developed drastically, but the industry has caused serious pollution to the environment, with increasing depletion of natural resources. Compared with other industries, the pollution caused by the chemical industry is large in area and great in quantity, and the complex composition of pollutants causes the very difficult governance process. Pollutants emitted in the chemical industry include atmospheric exhaust gas, industrial waste water, solid waste residue, the pollutants include higher content of heavy metals such as cadmium, mercury, lead, chromium, etc., and organic chemicals posing a serious hazard to the environment and human health, such as volatile phenols, PCBs and PAHs. These pollutants, once discharged without treatment or with substandard treatment, will be bound to be a potential risk to air, water, soil and other environment of China, and

ultimately endanger human health. The survey shows that the amount of wastewater generated by the chemical industry is 20%-23% of the national wastewater discharge volume, the exhaust gas emission accounts for 5%-7%, and the solid waste production volume such as industrial residue accounts for 8%-10% [1].

Environmental pollution has long been a key constraint to the industrial transformation and upgrading of the chemical industry and traditional pollution control is mostly concentrated at the end. However, this concept of "taking stop-gap measures" only exacerbates the difficulty of pollution control, and current pollution control measures and methods experience the problem of low efficiency and high cost, even causing secondary pollution [2]. Therefore, in the present context of vigorous promotion of building a "ecological civilization", the "recycling economy" and "green economy" thinking should run through the entire process of development of the industry, that is, transformation from the end control to source governance, change from afterwards treatment to prevention-orientation concept, vigorously strengthening clean production, developing green and advanced pollution control technologies, and establishing an "effective, stable, and economical" process of complete flow optimization pollution control [3]. The solution and treatment of environmental protection tasks in the chemical industry can not only protect our natural ecological environment, but also be conducive to sustainable and healthy development of economy and society of China, playing an important role in enhancing the economic and social benefits of the chemical industry, and promoting the sound sustainable development of the industry. Regarding the characteristics of the chemical industry such as much output pollutants and high energy consumption, the development of recycling economy resolves the conflict between environmental protection and economic development fundamentally and is the only way to achieve sustainable and healthy development of enterprises.

2. Research Methods
In this paper, the analytic hierarchy process was first used to decompose the relevant elements of decision-making into the target level, criterion level and indicator level, then the relative importance of decision-making schemes was determined by expert scoring and questionnaire surveys, and thus total ordering weights of all elements for the target were computed; finally using fuzzy comprehensive evaluation method, the level of ecological sustainable development of chemical enterprises was evaluated.

2.1. Analytic hierarchy process
Using the analytic hierarchy process (AHP), the various components or influencing factors of the research problem were divided into a hierarchical structure of the target level, criterion level, and index level according to the dominating relationship, thereby forming a multi-objective and multi-level model [4]. The basic steps of the AHP are as follows [5]: (1) Determine the decision-making goals, identify the factors that influence the decision-making, and classify them reasonably; (2) Compare the different factors in the same level with the same factors in the previous level, and determine their relative importance (Divided by "1-9 scale") to form a pairwise comparison matrix; (3) Calculate and verify if the pairwise comparison matrix has consistency. If pairwise comparison matrix does not have satisfactory consistency, it is necessary to adjust and modify the pairwise comparison matrix; (4) After reaching the consistency check, figure out the feature vector corresponding to the most obvious feature of the pairwise comparison matrix, then work out the proportion of each factor with respect to the same factor in the previous level, and then obtain the different weights of each factor by calculation, thus carrying out decision making.

Table 1. Index-related importance scale

Scale	Definition
1	I factor and j factor are equally important
3	I factor is slightly more important than j factor
5	I factor is more important than j factor
7	I factor is very important as compared with j factor
9	I factor is extremely important as compared with j factor
2, 4, 6, 6, 8	The importance is the median of the above scales

2.2.　Comprehensive evaluation method of fuzzy mathematics

By using the "membership" principle of fuzzy mathematics, the fuzzy comprehensive risk assessment method describes the fuzzy information that may exist in the assessment, uses certain mathematical methods for statistics and processing after determination of the weights, and finally obtains a scientific evaluation conclusion. The basic steps of fuzzy mathematical evaluation are as follows [6]: (1) Select indicators. Screen the influencing factors before evaluation, and determine the effective evaluation factors; (2) Based on the AHP, determine the evaluation set of weights, with the weights established to be consistent with the polarity and no negativity condition; (3) Establish an evaluation set; (4) Construct a fuzzy evaluation model. After the single-factor evaluation set for the set is established, a fuzzy evaluation model can be constructed, and calculation can be performed on the basis of fuzzy mathematical principles. It can be expressed by the following formula:

$$B=A \times R= (a1, a2, a3, am) \times \begin{bmatrix} r_{11} & r_{12} & \cdots & r_{1m} \\ r_{21} & r_{22} & \cdots & r_{2m} \\ \cdots & \cdots & \cdots & \cdots \\ r_{n1} & r_{n2} & \cdots & r_{nm} \end{bmatrix} = (b1, b2, b3, bum) \qquad (1)$$

Where, A is for a weight set, R for the score of rating evaluation, B for the index of the final fuzzy comprehensive rating.

3. Results

3.1.　Establishment of system indexes and calculation of weights by AHP

The sustainable development of an enterprise should include its uniform development in economic, social, and ecological environmental benefits, but since this article focuses mainly on the environmental benefits of the enterprise, selection will be only made from the relevant factors that affect the sustainable development of the ecological environment. The assessment of the sustainable development of chemical enterprises in the environment is a process that involves the comprehensive evaluation of multiple indicators. Therefore, the scientific choice of the evaluation index system is very important.　By expert scoring and questionnaire survey, this paper establishes evaluation indicators from three aspects, resource energy utilization (criterion level B1) that influences the sustainable development of the ecological environment (target level A), integrated waste disposal and emissions (standards level B2) and environmental protection expense input indicators (standard level B3), and the corresponding indicator layers are: unit output value resource consumption (C1), unit output value energy consumption (C2), energy recovery rate (C3), resource utilization rate (C4), soot and gas disposal rate and emissions (C5), industrial wastewater treatment efficiency and emissions (C6), industrial waste treatment and recovery (C7), environmental investment ratio (C8), pollution control input ratio (C9), ratio of environmental protection personnel (C10), and technology innovation input ratio (C11) . Using the harmonizing method, the eigenvalues and eigenvectors of a matrix are calculated, and the consistency of the matrix is judged, with specific calculation results stated as follows.

Table 2. Index weight of criterion level

	Judgment matrix			Consistency check	Weight w
	B1	B2	B3		
B1	1	3	5	λ max=3.0386	0.637
B2	1/3	1	3	CI=0.0193	0.258
B3	1/5	1/3	1	CR=0.0332<0.1,upcheck	0.105

Table 3. Index weight of index level

	Judgment matrix				Consistency check	Weight w
	C1	C2	C3	C4		
C1	1	8	5	3	λ max=4.0731	0.567
C2	1/8	1	1/2	1/6	CI=0.0243	0.056
C3	1/5	2	1	1/3	CR=0.0270<0.1,	0.104
C4	1/3	6	3	1	upchuck	0.273

Table 4. Index weight of index level

	Judgment matrix			Consistency check	Weight w
	C5	C6	C7		
C5	1	2	2	λ max=3.0536	0.493
C6	1/2	1	1/2	CI=0.0268	0.196
C7	1/2	2	1	CR=0.0462<0.1,upcheck	0.311

Table 5. Index weight of index level

	Judgment matrix				Consistency check	Weight w
	C8	C9	C10	C11		
C8	1	2	3	3	λ max=4.0104	0.455
C9	1/2	1	2	2	CI=0.0035	0.263
C10	1/3	1/2	1	1	CR=0.0039<0.1,	0.141
C11	1/3	1/2	1	1	upchuck	0.141

Table 6. Table of weights for environmental sustainable development assessment index system

Target level	Criterion level	Weight of criterion level	Index level	Weight of index level	Total weights
Environmental sustainable development of chemical enterprise	Utilization of resource energy	0.637	Unit output value resource consumption	0.567	0.36
			Unit output value energy consumption	0.056	0.04
			Energy recovery rate	0.104	0.07
			Resource utilization rate	0.273	0.17
	Disposal of "three wastes" and emission	0.258	Soot and gas disposal rate and emissions	0.493	0.13
			Industrial wastewater treatment efficiency and emissions	0.196	0.05
			Industrial waste treatment and recovery	0.311	0.08
	Investment of environmental protection expense	0.105	Environmental investment ratio	0.455	0.05
			Pollution control input ratio	0.263	0.03
			Ratio of environmental protection personnel	0.141	0.01
			Technology innovation input ratio	0.141	0.01

3.2. Calculation of environmental sustainable development level of enterprises using fuzzy comprehensive evaluation method.

The object assessed by the fuzzy comprehensive evaluation method is a chemical manufacturing enterprise. The main pollutants discharged are mainly atmospheric pollutants, and the amount of industrial wastewater and waste slag is relatively small. The weights calculated in Table 4 were used to evaluate the sustainable development level of ecological environment of the enterprise. For the sake of scientific and objective evaluation, a checklist of evaluation index systems was prepared. Table 5 shows the evaluation grades of the indicators of sustainable development of the ecological environment of the enterprise given by expert scoring. " √ "was used to determine the remark rating of each indicator in the project hierarchy, and the degree of membership of each level was calculated.

Table 7. Table of remark rating determination√

Factors	Items		Descriptive grades				
			1 Good	2 Better	3 Fair	4 Worse	5 Poor
Environmental sustainable development of chemical enterprise(A)	Resource energy utilization (B1)	unit output value resource consumption(C1)			√		
		unit output value energy consumption(C2)			√		
		energy recovery rate(C3)		√			
		resource utilization rate(C4)			√		
	Membership of B1			0.25	0.75		
	Disposal of "three wastes" and emission(B2)	soot and gas disposal rate and emissions(C5)			√		
		industrial wastewater treatment efficiency and emissions(C6)			√		
		industrial waste treatment and recovery(C7)		√			
	Membership of B2			0.33	0.67		
	Investment of environmental protection expense(B3)	environmental investment ratio(C8)			√		
		pollution control input ratio(C9)			√		
		ratio of environmental protection personnel(C10)			√		
		technology innovation input ratio(C11)			√		
	Membership of B3				1.0		

Calculation using fuzzy comprehensive evaluation method is shown in the following formula:

$$B = A \times R = (0.637 \ 0.258 \ 0.105) \times \begin{bmatrix} 0 & 0.25 & 0.75 & 0 & 0 \\ 0 & 0.33 & 0.67 & 0 & 0 \\ 0 & 0 & 1 & 0 & 0 \end{bmatrix} = (0, 0.244, 0.756, 0, 0) \qquad (2)$$

According to the principle of maximum degree of membership, B = 0.756 was obtained through calculation, and the level of sustainable development of the ecological environment of the enterprise was determined as "Fair".

4. Discussion

The CPC National Congress proposed: construction of ecological civilization is a millennial plan for sustainable development of our country, persistence of the harmonious coexistence between man and nature is an important part of development of socialism with Chinese characteristics in the new era,

and thus, ecological civilization construction and environmental protection has also be promoted to an unprecedented strategic height. Sustainable development emphasizes the harmony between man and nature, and vigorous promotion of the recycling development, green development and low-carbon production. The research in current stage mainly involves the sustainable development of economy, sustainable development of ecology, and sustainable development of society. This article focuses on the study of the ecological sustainable development of chemical enterprises, that is, environmental protection, resource utilization, and control of pollutant emissions.

The chemical industry is a traditional resource and energy consuming industry. The contradiction between its purpose of economic development and the constraints of resources and environment is relatively prominent. Due to the characteristics of the industry itself, the types of pollutants and emissions are more than other industries, and this has become the main cause of environmental and ecological unsustainable development of the enterprises. Using the AHP and the fuzzy evaluation method, this article has obtained the "Fair" level of the sustainable development of ecological environment of the evaluation object – a chemical enterprise. This requires chemical enterprises to change the traditional model of economic development that is, adhering to dualistic development of economy and environment, establishing an economic development mode in line with ecological harmony, emphasizing on energy conservation, rational use of resources, enhancing the investment environment, and implementing cleaner production throughout the process. Specifically: First, chemical companies try to achieve ecological sustainable development in the whole production process, namely, the establishment of a circulatory system for waste and water, gas and other energy, and reduction of energy consumption and material consumption; second, pay attention to clean production and recycling. Enterprises should use environmentally friendly and renewable clean energy as much as possible, and moreover, maximize the recovery and recycling of waste; fully recycle and utilize the resources or wastes that overflow from each link, promote the transformation of waste to resources and achieve the purpose of resources recycling; thirdly, To realize the sustainable development of the enterprises and even the entire industry, increase technological innovation and R&D investment, because the technological innovation and R&D capabilities of the enterprises play an important role in the recycling economy development and pollution control [7]. If the industry can attach importance to innovation and scientific research, take the necessary incentives, and through increased innovation and intra-industry technological upgrading and transformation, it can achieve the purpose of sustainable development in water conservation, energy conservation, reduction and reclamation of pollutants and wastes.

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