Applied Research of Cleaner Production Evaluation System in Wig Industry

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Abstract: An assessment indicator system of cleaner production in wig industry was built in this article, which intended to meet the shortage of corresponding standards of cleaner production evaluation in the national wig industry. An assessment route of cleaner production index system of the wig industry was established. Based on analysis of the production process and pollution node of the wig industry, the cleaner production index system of wig industry was established for the first time, which contained 6 first-level indicators and 22 second-level indicators. The evaluation indicator baselines were set out in accordance with the cleaner production standards and index systems in other areas when the actual data of each index of the wig enterprises was analyzed statistically. Then, the importance of every index was confirmed by analytic hierarchy process (AHP) and an AHP-Fuzzy comprehensive evaluation model was introduced by utilizing the fuzzy mathematics method. What is more, in order to test and verify the accuracy of the evaluation system, this evaluation system was applied to estimate the cleaner production level of a wig enterprise in Henan province. It was found that the advanced level of this wig company should be 0.1352, as against the membership of the general level was 0.0391, which could be compared to the basic level of 0.0298. The result is consistent with the actual situation of the enterprise, which proves that the system is feasible and can be used to tap the cleaner production potential of wig enterprises and promote the sustainable development of the wig enterprises.
Keywords: environmentalology; wig industry; cleaner production; evaluation indicator system; AHP-Fuzzy comprehensive evaluation.

1. Introduction

Hair products are made of animal hairs, human hairs or synthetic fibers. Through a series of production processes, wig products are mainly used in hair ornaments, beauty salon teaching and making up for the lack of hair loss and other physical defects to meet the requirements of specific professions (e.g. performers, lawyers, and other industries), etc.[1] In recent years, people's pursuit of fashion and beauty has increased, and so has the demand for wig products. China is the production base of global hair products, and the total exports of its products account for more than 80% of the number of human hair wigs in the same industry around the world, and more than 50% of the chemical fiber wigs.

China's wig industry is booming, but at the same time, it is one of the industries with high pollutant emissions.[2] The production wastewater of wig industry has the characteristics of "three high (high COD, high ammonia nitrogen and high chromaticity) and three low (low ratio of carbon and nitrogen, low bioavailability, low stability of water quality)" because there are many different production processes in wig industry with uneven techniques and low reusable rates of acid, alkali, hair dye and water used in the production process, which poses a great threat to the environment. As the country's increasingly strict environmental and industrial policies, the wig industry is faced with the great pressure of water-saving and emission reduction., so it is urgent to carry out "whole process" cleaner production in wig industry to control pollutants at the source. Therefore, in order to protect the environment and ensure the sustainable development of the industry, the government and environmental protection departments have put forward strict requirements on cleaner production of wig industry and audited some key wig enterprises in accordance with *Interim Administrative Measures of National Cleaner Production Audit*.[3] However, since there has been no research on establishing a cleaner production standard or evaluation system for the wig industry, it is difficult to promote cleaner production in the wig industry, while making how to make an objective and reasonable evaluation of the CP level of a wig company be a problem. In this situation, the establishment of a sound CP evaluation system in wig industry has become the target of the industry's sustainable development.

Many researchers conducted wide and in-depth researches on the CP evaluation system of various industries.

However, there were few researches on hair products industry, but some scholars still studied the evaluation system of cleaner production in similar industries. Yang[4] interpreted the cleaner production standards of textile industry (cotton dyeing) from 6 aspects: production process and equipment requirements, raw material requirements, resource consumption and pollutant production indicators, product indicators, environmental management requirements. And the index system of water-saving and emission reduction in printing and dyeing industry was constructed from 4 aspects: water resource indicator, main raw materials and additive consumption indicator, pollutants creation indicator, and comprehensive utilization indicator (O. Tong [5] 2012). These results provide reference ideas and methods for the construction of CP evaluation system in the wig industry.

Therefore, in order to assist the wig enterprises to assess their own CP level and find the existing deficiency and key links with cleaner production potential, a quantifiable evaluation index system of cleaner production in the wig industry was studied in this paper, which intended to help to carry out quantitative assessment of the wig enterprises' cleaner production work, and to some extent guide the healthy, orderly and sustainable development of hair products industries.

2. Evaluation Route

The construction of cleaner production evaluation system in wig industry mainly includes analysis of production process and emission characteristics of the industry, construction of a reasonable evaluation index system, determination of the index baselines, evaluation of CP level of wig factories based on using AHP-Fuzzy comprehensive evaluation method. The concrete CP evaluation route is outlined in Fig. 1.

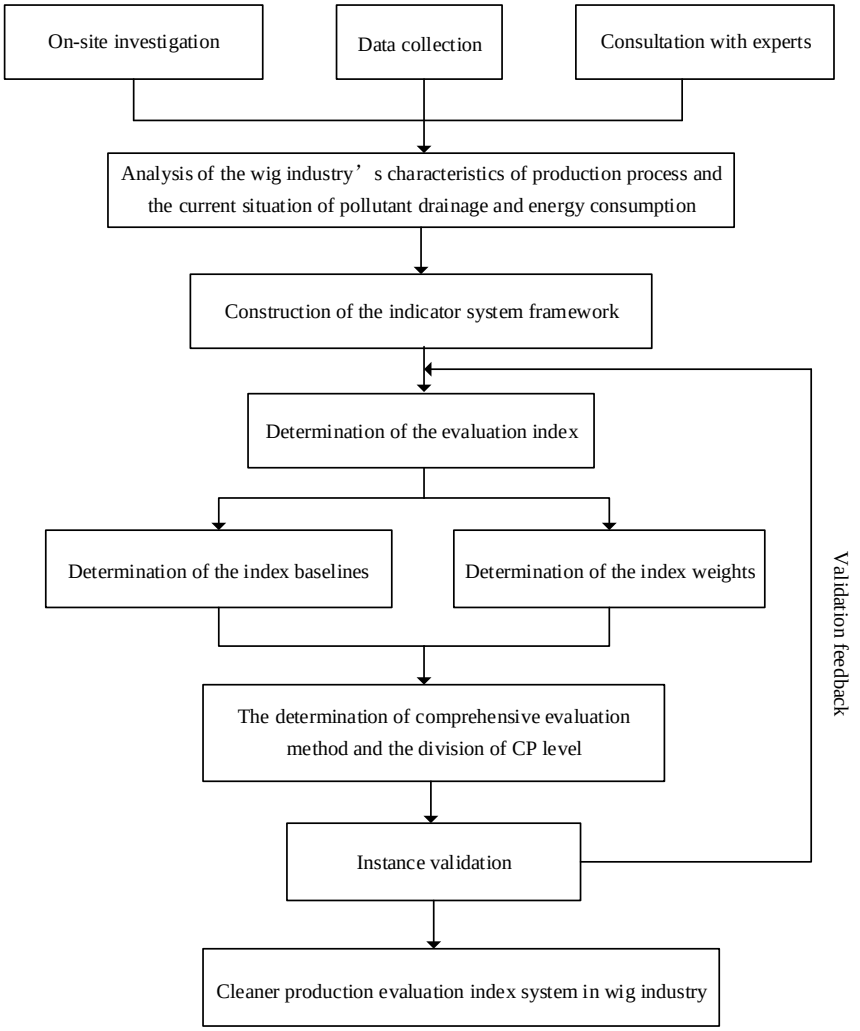

Fig. 1 Assessment route of cleaner production evaluation system in wig industry

3. Production Process and Pollution Characteristics

By conducting field investigation, studying relevant materials and consulting the experts of wig industry, the characteristics of wig production process and the discharge nodes of each process are shown in Fig. 2.[6]

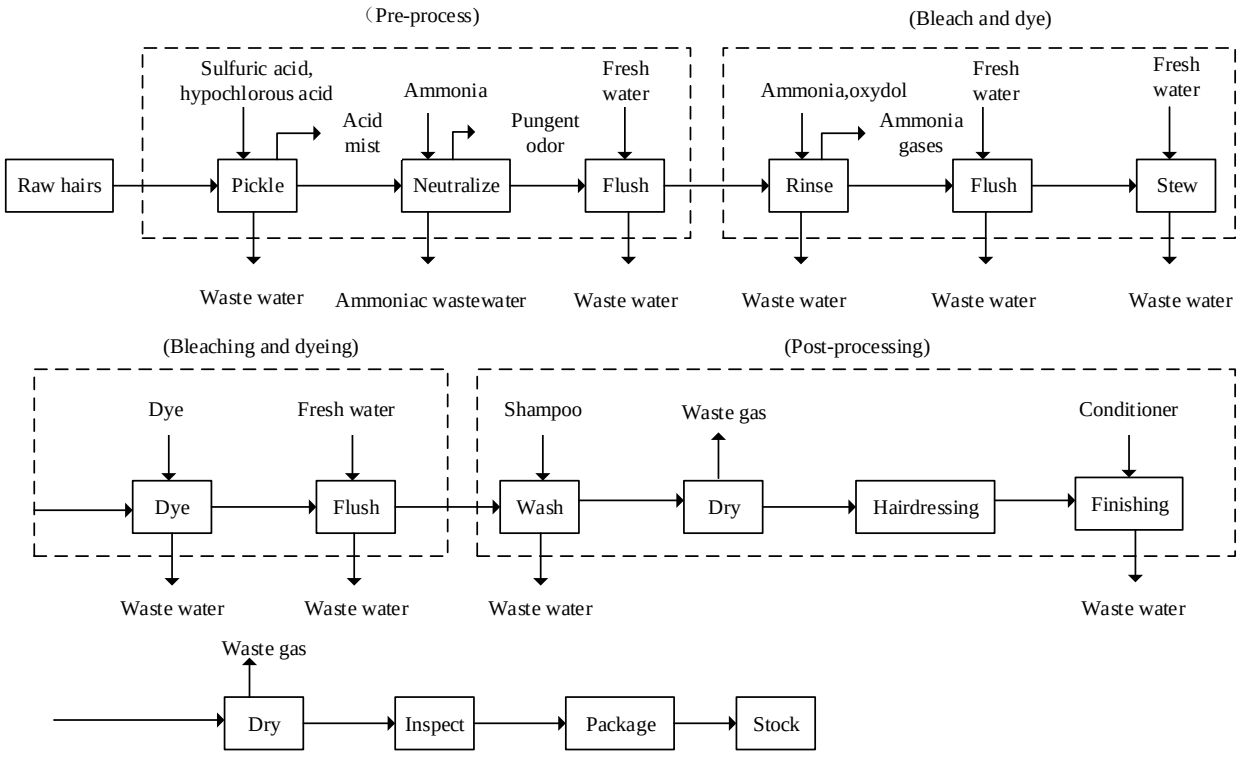

Fig. 2 Production processes and pollution nodes of the wig industry

According to the analysis of Fig. 2, the contaminants of hair products industry mainly come from pretreatment, bleaching and dyeing, washing and post-processing. In addition, based on the analysis of the references and research results[2], the waste water produced in the pretreatment process which is in a high level of pollutants accounts for about 40% of the total waste water; the waste water produced in the dyeing process accounts for about 30%, which mainly contains residual dye and a large amount of residual auxiliaries that can produce high concentration of pollutants; the waste water produced in the post process accounts for about 30%, which mainly contains finishing auxiliaries, etc. Besides, there are also acid mists and ammonia waste gases produced in the processes of acid cleaning, neutralizing, bleaching, dyeing, washing, reprocessing and drying, along with solid wastes (such as broken hairs, dehydrated sludge, municipal waste, etc.) produced in the whole production process. Therefore, these factors should be considered when selecting indicators.

4. The Establishment of Cleaner Production Evaluation Indicator System in Wig Industry

4.1 Selection Principles of Evaluation Indicators

The reasonable selection of cleaner production evaluation indexes determine the accurate assessment of the actual CP level.[7] In order to construct a reasonable cleaner production index system in wig industry, the following basic principles are mainly followed.[8,9]

1) Principle of objective and accurate assessment. The selected indexes should be able to objectively reflect the actual production process characteristics of the wig industry, and the index concept can clearly and accurately measure the structure and function of the industry production system.

2) Principle of life cycle assessment (LCA). The environmental impact assessment should consider the entire life cycle of wig industry.

3) Principle of pollution prevention. It is necessary to take account of the impact of the use of raw materials and resource energy on the cleaner production process, but not only concern about the production of terminal contaminants.

4) Principle of combination of quantitative and qualitative indicators. Besides of the quantitative indicators, there are also indicators that can't be described quantitatively, such as production technology and equipment, environmental management, so it's necessary to introduce qualitative indicators to describe the production process comprehensively.

5) Principle of continuous improvement. Because of different CP levels of domestic wig factories, different index levels should be distinguished in the index system while considering various technology and management ability in different enterprises, in order to guide the enterprises to choose different cleaner production goal to reach a higher development level according to their own situation.

4.2 Establishment of Evaluation Indicator System and Determination of Baseline

4.2.1 Establishment of evaluation indicator system

At present, the main indicators adopted in formulating the industry cleaner production standard and evaluation index system are production process (and equipment), products, resources and energy utilization, pollutant emissions, waste recycling, and environmental management requirements, etc.[10,11] According to analysis of the characteristics of production and pollution nodes in wig industry, combining with the index selection principles, cleaner production standards in other industries[4,12], the evaluation index systems[13] and cleaner production audit cases of some wig enterprises, cleaner production evaluation index system in wig industry was built, which contained three layers. The first layer is the target layer, namely the cleaner production evaluation indicator system in wig industry; the second layer is the rule layer, which contains 6 primary indicators; the third layer is the index layer, which describes each secondary index. The specific indicator system is shown in Fig. 3.

4.2.2 Determination of indicator baseline

In order to obtain scientific and reasonable index value, on the basis of a lot of literature studies, field investigation and experts consultation, combining with *Cleaner Production Promotion Law*, the domestic existing pollutant emission standards, cleaner production audit reports and actual situation in wig industry, every cleaner production indicator baseline in wig industry was determined in accordance with the general principles of baseline determination of *General Provisions on the Establishment of Evaluation Index System for Cleaner Production (Trial Draft)*. They are shown in Table 1. We selected current reference values that 5% of the domestic wig enterprises can achieve as I- level baselines, 20% of the enterprises can achieve as II- level baselines, 50% as III- level baselines.[7]

5. Evaluation Methodology

5.1 Determination of Index Weight

At present, the commonly used methods to determine the weight values are expert consultation, principal component analysis, analytic hierarchy process (AHP), etc. The AHP is applicable to the multi-objective decision problem, combining quantitative analysis with qualitative analysis while fully considering the relative importance of each index, and hierarchical affiliations between various elements are processed relatively by mathematical means, which is more objective.[14] Therefore, based on the characteristics of the cleaner production evaluation index system in wig industry, the weight of each index was determined in this paper by the AHP.

By using the method of 1 - 9 scale, the relative importance of indexes at all levels was first evaluated, in order to construct the judgment matrix, and then calculated with the Yaahp software.[5] And the weight values of each index were shown in Table 2 and 3. After the consistency test, all CR < 0.1, indicating that the weight values of all indexes are consistent with the consistency requirement.

5.2 Comprehensive Evaluation Method

Fuzzy comprehensive evaluation method is a comprehensive evaluation method based on fuzzy mathematics, which is on the basis of AHP. After determining the weights of indexes by AHP, the memberships of the evaluation factors between fuzzy relations were determined in Fuzzy method and the system constrained by a variety of complex and uncertain determinants was evaluated comprehensively, so as to solve the contradictions between the complexity of the system and the accuracy the evaluation.[15,16] Considering diversity of the factors involved in wig industry and complexity of the system, the fuzzy comprehensive evaluation method was used in this paper, which included the procedures as follows: establishing the evaluation object factor set U, constructing the evaluation set V, single factor fuzzy judgment, and fuzzy comprehensive evaluation, etc.

5.2.1 Construction of fuzzy matrix and membership function

U was set as the factor set in the cleaner production evaluation system of wig industry in this article, which included six evaluation factor values that were identified in the preceding text, namely six first-grade indicators. Meanwhile, V was set to be the collection of judgments corresponding to U, which contained three levels. Referring to the level division of cleaner production standards in other similar industries in China, these 3 judgment levels included I- level (domestic advanced CP level), II- level (domestic general CP level) and III- level (domestic basic CP level).

$U = \{U_1, U_2, U_3, \ldots, U_6\}$, U_i is the evaluation factor (evaluation index); $V = \{V_1, V_2, V_3\}$, V_j is the evaluation level.

If all the elements in U are evaluated as a single factor respectively, then decision makers can obtain fuzzy relation matrix R from U to V.

$$R = \begin{bmatrix} r_{11} & \cdots & r_{1j} \\ \vdots & \ddots & \vdots \\ r_{i1} & \cdots & r_{ij} \end{bmatrix}$$

In the formula, $R_{i\times j}$ is a single factor evaluation matrix; r_{ij} indicates the degree that i index belongs to the judgment level j, that is, membership degree, $0 \le r_{ij} \le 1$ ($i = 1, 2, \ldots; j = 1,2,3$).

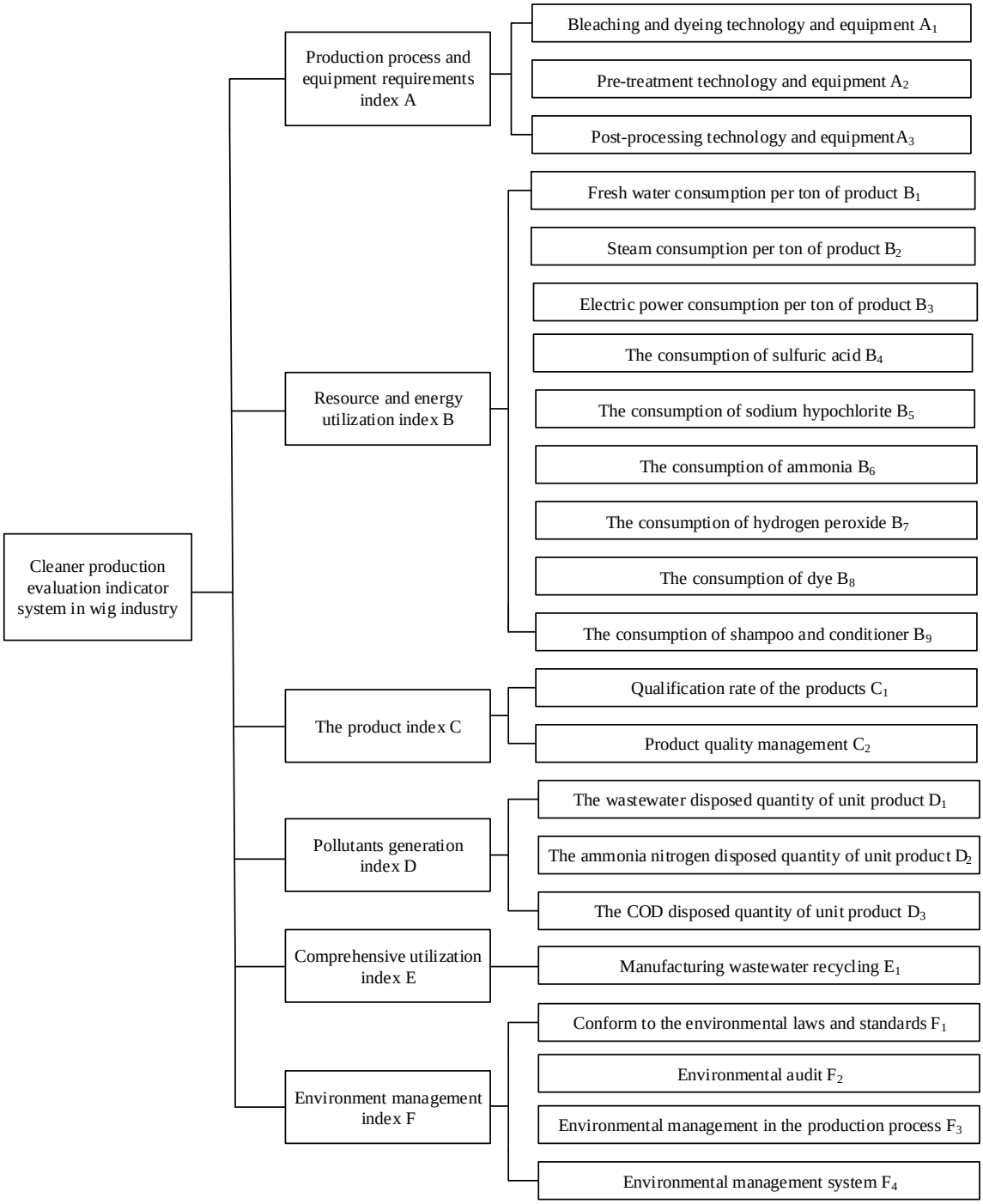

Fig. 3 Cleaner production assessment indicator system for wig industry

Table 1. Baseline of the cleaner production assessment indicators for wig industry

Grade 1 indicator	Grade 2 indicator	I- level baseline	II- level baseline	III- level baseline
A	A_1	Automatic dyeing machine, dyeing and finishing joint equipment; some products are pickled, neutralized, bleached and dyed in a pot automatically; a small amount of manual operations.	Some products are pickled, neutralized, bleached and dyed in a pot automatically; some are pickled, neutralized, bleached and dyed in corresponding pots sequentially; some manual operations.	Some products are pickled, neutralized, bleached and dyed in corresponding pots sequentially; some are treated in a pot automatically; some manual operations.
	A_2	Hairs are winded to wefts by using dewatering machine, drying room (machine), passing machine, merging machine, high needle machine, three-head weft machine and other equipment; some manual operations.	Hairs are winded to wefts by using dewatering machine, drying room (machine), passing machine(or handwork), merging machine, high needle machine, three-head weft machine and other equipment; most manual operations.	
	A_3	Manual hair cleaning, dry in drying room, manual packaging storage.		
B	B_1 (t/t)	≤190	≤350	≤450
	B_2 (t/t)	≤60	≤80	≤90
	B_3 (kW. h/t)	≤300	≤400	≤550
	B4 (t/t)	≤0.05	≤0.15	≤0.2
	B_5 (t/t)	≤0.1	≤0.5	≤0.7
	B_6 (t/t)	≤0.2	≤0.5	≤0.8
	B_7 (t/t)	≤0.15	≤0.3	≤0.5
	B_8 (kg/t)	≤5	≤10	≤20
	B_9 (kg/t)	≤10	≤50	≤100
C	C_1 (%)	≥90	≥80	≥70
	C_2	Passing quality management system certification of ISO 9001.		Not passing
D	D_1 (t/t)	≤170	≤200	≤400
	D_2 (kg/t)	≤5	≤8	≤10
	D_3 (kg/t)	≤20	≤40	≤60
E	E_1 (%)	≥25	≥10	≥5
F	F_1	Complying with national, local environmental laws and regulations. Meeting the requirement of national, local and industrial pollutant discharge standards, the request of total amount of pollutant and pollution permit management.		
	F_2	Implementing the enterprise cleaner production audit; Environmental management manual, procedures and operating documents are available; The environmental management system is sound, and the original records and statistics are fully valid. Establishing environmental audit system, assessment system and environmental responsibility system.		Failing to implement the enterprise cleaner production audit; The environmental management manual, procedures and working documents are basically in preparation; The environmental management system is basically sound, and the original records and statistics are basically complete. Establishing environmental audit system, assessment system and environmental responsibility system basically.
	F_3	The production devices are closed; The main production line or production unit is equipped with metering unit to record continuous display statistics, and the water, energy consumption are assessed. The main production process is automatic; Strengthening maintenance of the equipment; Cleaning the workshop; Completely eliminate running, emitting, dripping and leaking.		The production devices are not closed; Production line or production unit is equipped with metering unit, but fail to record continuous display statistics, and the water, energy consumption are assessed basically; Strengthening maintenance of the equipment; Cleaning the workshop; Be able to prevent running, emitting, dripping and leaking.
	F_4	Passing the quality management system, environmental management system, occupational health management system certification; Implementing environmental training for employees and establishing rewards and punishment systems; Establishing a relatively perfect environment management organization.	Failing to pass the quality management system, environmental management system, occupational health management system certification; Failing to implement environmental training for employees and failing to establish rewards and punishment systems; Establishing an environment management organization.	

Membership degree is calculated by membership functions. The membership function is used to indicate the approximation degree of the evaluation object factor set U_i to V_j level in the judging set V.[17] At present, there are many kinds of membership functions, semi-trapezoidal distribution function that has been widely used was applied in this paper.[18]

When the index value is larger, the lower the CP level is, that is, $V_1 < V_2 < V_3$. Besides, the grade of membership should be expressed by the descending half trapezoidal distribution function, and the case of $V_1 > V_2 > V_3$ is shown in brackets.

$$R_1 = \begin{cases} 1 & 0 \le U \le V_1\ (U \ge V_1) \\ \frac{V_2 - U}{V_2 - V_1} & V_1 \le U \le V_2 (V_2 < U < V_1) \\ 0 & U \ge V_2\ \ (0 < U \le V_2) \end{cases}$$

$$R_2 = \begin{cases} 0 & U \le V_1\ or\ U \ge V_3 (U \ge V_1\ or\ U \le V_3) \\ \frac{U - V_1}{V_2 - V_1} & V_1 < U < V_2 (V_2 < U < V_1) \\ \frac{V_3 - U}{V_3 - V_2} & V_2 < U < V_3 (V_3 < U < V_2) \\ 1 & U = V_2 \end{cases}$$

$$R_3 = \begin{cases} 0 & U \le V_2 (U \ge V_2) \\ \frac{U - V_2}{V_3 - V_2} & V_2 < U \le V_3 (V_3 < U < V_2) \\ 1 & U \ge V_3 (U \le V_3) \end{cases}$$

5.2.2 Fuzzy comprehensive evaluation and determination of evaluation level

Fuzzy comprehensive evaluation includes first-grade and second-grade Fuzzy comprehensive evaluation. In order to take the impact of every indicator on the cleaner production in wig industry into account comprehensively, the second-grade fuzzy comprehensive evaluation is the compound operation of weight vector W and fuzzy relation matrix R with the formula $Y = WR$, and its calculation formula is:

$$Y = W \cdot R = \left(w_1, w_2\ ,\ \cdots\ ,\ w\right) \cdot \begin{pmatrix} r_{11} & \cdots & r_{1j} \\ \vdots & \ddots & \vdots \\ r_{i1} & \cdots & r_{ij} \end{pmatrix} = (y_1, y_2, \cdots, y_i);$$

$$y_i = min\left[\sum_{i=1}^{m} W_i r_{ij}\ , 1\right], \quad \sum_{i=1}^{m} y = 1.$$

$w_1, w_2\ ,\ \cdots, w$ is the weight of each indicator, r_{ij} is the membership degree that index i belongs to level j in the evaluation set, y_i is the possible value of each CP level in the evaluation set.

The first-level fuzzy comprehensive evaluation was based on the results of the second-level fuzzy comprehensive evaluation, and then through the calculation of Fuzzy evaluation, we got decision-making set Y. Finally, the CP level of the evaluation object is determined according to the principles of maximum degree of membership.

6. Case Study

6.1 Data Collection

The method described above was applied to a certain wig company in Henan province. The actual value of each index is shown in Table 2.

6.2 Results

After determining the weight of each indicator by AHP and making sure the subject degree of every index of the indicator layer by using membership function according to actual values and baselines, the results are shown in Table 2. And the importance and subject degree of every index of the criteria layer that were calculated are shown in Table 3.

According to the results in Table 3, this wig company' s membership degree of CP level is 0.1352, of general level is 0.0391, and of basic level is 0.0298. So it is obvious that this wig enterprise is at a domestic CP level, coinciding with the company's actual cleaner production situation. Above all, it is proved that this indicator system is feasible, which can be applied to evaluate the CP levels of wig enterprises.

From the above data, it can be concluded that this enterprise has some problems such as low utilization of energy, low rate of waste recycling and large quantity of pollutants in cleaner production, which need to be improved.

7. Conclusion

1) The evaluation index system of cleaner production in wig industry was set up firstly in this paper through the analytic hierarchy process, which filled in the blank of the domestic cleaner production standards and the evaluation index systems in wig industry. However, the development of process equipment and technology of wig enterprises is so fast, therefore this evaluation index system needs to keep up with times and keep updating and improving.

Table 2. Existing value and importance and subject degree of every index of a wig enterprise

Indicator layer	Actual value	Weight	Index membership degree		
			CP level	General level	Basic level
A_1	Automatic dyeing machine, dyeing and finishing joint equipment; some products are pickled, neutralized, bleached and dyed in a pot automatically; a small amount of manual operations.	0.1138	1	0	0
A_2	Hairs are winded to wefts by using dewatering machine, drying machine, passing machine, merging machine, high needle machine, three-head weft machine and other equipment; some manual operations.	0.0547	1	0	0
A_3	Manual hair cleaning, dry in drying room, manual packaging storage.	0.0547	1	1	1
B_1	150	0.0540	1	0	0
B_2	25	0.0469	1	0	0
B_3	600	0.0468	0	0	1
B_4	0.1	0.0446	0.500	0.500	0
B_5	0.13	0.0443	0.925	0.075	0
B_6	0.3	0.0434	0.667	0.333	0
B_7	0.64	0.0434	0	0	1
B_8	10	0.0391	0	1	0
B_9	10	0.0382	1	0	0
C_1	93	0.0310	1	0	0
C_2	Passing quality management system certification of ISO 9001.	0.0291	1	1	1
D_1	215	0.0283	0	0.925	0.075
D_2	4.71	0.0258	1	0	0
D_3	28.3	0.0238	0.585	0.415	0
E_1	24	0.0156	0.933	0.067	0
F_1	Complying with national, local environmental laws and regulations. Meeting the requirement of national, local and industrial pollutant discharge standards, the request of total amount of pollutant and pollution permit management.	0.0088	1	0	0
F_2	Implementing the enterprise cleaner production audit; Environmental management manual, procedures and operating documents are available; The environmental management system is sound, and the original records and statistics are fully valid. Establishing environmental audit system, assessment system and environmental responsibility system.	0.0088	1	0	0
F_3	The production devices are closed; The main production line or production unit is equipped with metering unit to record continuous display statistics, and the water, energy consumption are assessed. The main production process is automatic; Strengthening maintenance of the equipment; Cleaning the workshop; Completely eliminate running, emitting, dripping and leaking.	0.0066	1	0	0
F_4	Passing the quality management system, environmental management system, occupational health management system certification; Implementing environmental training for employees and establishing rewards and punishment systems; Establishing a relatively perfect environment management organization, such as safety and environmental protection department.	0.0051	1	0	0

Table 3. Importance and subject degree of every index of the criteria layer

Rule layer	Weight	Index membership degree		
		CP level	General level	Basic level
A	0.1213	0.2777	0.0547	0.0547
B	0.2475	0.231	0.0792	0.0902
C	0.0625	0.0601	0.0291	0.0291
D	0.2875	0.1249	0.0593	0.0045
E	0.1509	0.0321	0.0055	0
F	0.1303	0.0354	0	0
Target layer	1	0.1352	0.0391	0.0298

2) In the past, the review and evaluation of the cleaner production in wig enterprises were not evaluated accurately nor scientifically, because they were mostly based on the subjective experience judgment from industry experts and staffs without scientific quantitative evaluation. The AHP fuzzy comprehensive evaluation model was adopted in this paper to evaluate the cleaner production of wig industry quantitatively, which intended to overcome the disadvantages of poor objectivity and scientific inactivity in the process of cleaner production evaluation.

3) Through the application of this evaluation system to a wig enterprise in Henan province, the evaluation result was consistent with the actual production situation of the enterprise, which proved that this evaluation system could provide a powerful evaluation tool for the wig company to evaluate its own CP level, measure its international (domestic) level in the same industry and discover its existing deficiency. We can also use this system to provide technical support for cleaner production audit of wig enterprises, and to provide bases for environmental impact assessment and establishment of the projects of the new construction and expansion of factories. It can also guide the enterprises to research for application of new technology to reduce pollution and decrease drainage, and to promote green production process and wig products, walking the road of sustainable development.

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