Evaluation of Advanced Treatment Technology of Dyeing Wastewater Based on Analytic Hierarchy Process

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Abstract. Determining the weight of the evaluation index is an important prerequisite for the evaluation of advanced wastewater treatment technology in the printing and dyeing industry. The article builds an evaluation model of 10 indicators of advanced treatment technology for printing and dyeing wastewater from three aspects: environmental benefits, economic benefits, and technical performance. Furthermore, the analytic hierarchy process was used to determine the weight of each index of the evaluation system. The calculation results show that the consistency ratios of the established judgment matrices are all less than 0.1, which has a good consistency, and the hierarchical single-ranking results all meet the requirements of consistency test. Therefore, the evaluation value of the advanced treatment technology of printing and dyeing wastewater calculated by AHP is more accurate and reliable. It can provide technical support for the next step of evaluating the performance of printing and dyeing wastewater treatment.

1. Introduction

Due to the large amount of waste water discharged from the textile printing and dyeing industry, high concentration, high chroma, and difficult degradation, the printing and dyeing process has been ranked among the heavily polluting industries. With the country's increasing emphasis on environmental protection, it is imperative to increase its emission standard value. Due to the increasingly strict emission standards and rising water charges, printing and dyeing enterprises have turned their attention to the in-depth treatment and reuse of printing and dyeing wastewater. At present, most of the methods for reuse of printing and dyeing wastewater after advanced treatment are based on existing wastewater treatment facilities, which are upgraded and reconstructed, that is, the traditional biological secondary treatment is followed by advanced treatment to meet the reuse requirements. In recent years, in order to realize the reuse of printing and dyeing wastewater after extensive treatment, people have carried out extensive research on physical, chemical, biological and other wastewater treatment technologies, and have been verified in engineering practice. Analytic Hierarchy Process is often used in the comprehensive evaluation of environmental quality in the fields of environmental engineering and environmental science[1], and application to comprehensive assessment of pollution treatment facilities and technologies[2]. Analytic Hierarchy Process (AHP) is a decision analysis method that can combine qualitative and quantitative analysis. It has a wide range of practicalities for decision analysis of various types of problems. It is an effective tool for solving multi-objective, multi-level, and complex systems[3].

2. Construction of AHP Index System Model

The analytic hierarchy process was proposed by Professor T. L. Saaty. It decomposes complex
problems into various constituent factors, and then groups these factors into dominance relationships to form a hierarchical model. The relative importance of factors in the hierarchy is determined by pairwise comparisons, and then the judgments of decision makers are integrated to determine the relative importance of decision plans[4].

A common method for establishing an indicator system is to first divide the target into specific target layers and criterion layers, and then subdivide it into smaller small systems that can establish indicators. Through the establishment of indicators for these small systems, the entire indicator system is established[5]. The target layer of this study is the technical index system for advanced treatment of printing and dyeing wastewater. Environmental benefits, economic benefits, and technical performance are the first-level indicators belonging to the target layer. The indicator layer is a secondary indicator. This layer belongs to the criterion layer. It is a specific indicator that reflects all aspects of the processing process and is easy to evaluate and evaluate. There are ten indicators in total. As shown in Figure 1.

Figure 1. Hierarchical structure of printing and dyeing wastewater advanced treatment technology

3. Determination of indicator weights

In this paper, the evaluation index weight of the advanced treatment scheme of printing and dyeing wastewater is determined by analytic hierarchy process. The degree of importance of the index is in the form of scoring by an expert group of 10 professional and technical personnel including environmental protection, pulp and paper, and social fields through an E-mail questionnaire. The scoring scale is represented by Saaty's 1-9 scale[6]. The calculation formula of consistency test is shown in formula (1) and formula (2):

\[
CI = \frac{\lambda_{max} - n}{n - 1} \tag{1}
\]

\[
CR = \frac{CI}{RI} \tag{2}
\]

Finally, four judgment matrices are obtained, as shown in Tables 1 to 4.
Table 1. Target layer (A) weight judgment matrix

|   | A   | B1  | B2  | B3  | Weights |
|---|-----|-----|-----|-----|---------|
| B1| 1   | 1   | 2   | 0.413 |
| B2| 1   | 1   | 1   | 0.327 |
| B3| 1/2 | 1   | 1   | 0.260 |

$\lambda_{max} = 3.054; \ CI = 0.267; \ CR = 0.046 < 0.1$

It can be seen from Table 1 that the environmental benefit B1 and the economic benefit B2 are equally important compared to each other; Compared with the environmental benefit B1 and the technical performance B3, the former is slightly more important than the latter. The economic benefit B2 and the technical performance B3 are equally important.

Table 2. Weight judgment matrix for environmental benefits (B1)

|   | B1  | C1  | C2  | C3  | Weights |
|---|-----|-----|-----|-----|---------|
| C1| 1   | 1   | 1/2 | 0.250 |
| C2| 2   | 2   | 1   | 0.500 |
| C3| 1   | 1   | 1/2 | 0.250 |

$\lambda_{max} = 3.000; \ CI = 0; \ CR = 0 < 0.1$

Table 3. Economic Benefits (B2) Weight Judgment Matrix

|   | B2  | C4  | C5  | C6  | Weights |
|---|-----|-----|-----|-----|---------|
| C4| 1   | 1/2 | 1   | 0.240 |
| C5| 3   | 1   | 2   | 0.549 |
| C6| 1   | 1/3 | 1   | 0.210 |

$\lambda_{max} = 3.018; \ CI = 0.009; \ CR = 0 < 0.16$

Table 4. Technical performance (B3) weight judgment matrix

|   | B3  | C7  | C8  | C9  | C10 | Weights |
|---|-----|-----|-----|-----|-----|---------|
| C7| 1   | 1   | 1/2 | 2   | 0.227 |
| C8| 1/2 | 1/2 | 1   | 1/3 | 0.123 |
| C9| 1   | 1   | 1/2 | 2   | 0.227 |
| C10| 2   | 2   | 3   | 1   | 0.423 |

$\lambda_{max} = 4.010; \ CI = 0.003; \ CR = 0.003 < 0.16$

After obtaining the weights of each criterion layer and index layer, according to the overall ranking principle of the analytic hierarchy process, the ranking weight value of each indicator to the "best technology" of the total target is obtained. The results are shown in Table 5.

Table 5. Total ranking results of evaluation indicators

|   | A     | B1  | B2  | B3  | Total weight | Sort |
|---|-------|-----|-----|-----|--------------|-----|
| C1| 0.413 | 0.327| 0.260| 0.103| 4             |
| C2| 0.500 | 0   | 0   | 0.206| 1             |
| C3| 0.250 | 0   | 0   | 0.103| 4             |
| C4| 0     | 0.240| 0   | 0.078| 5             |
| C5| 0     | 0.549| 0   | 0.179| 2             |
| C6| 0     | 0.210| 0   | 0.068| 6             |
| C7| 0     | 0   | 0.227| 0.059| 7             |
| C8| 0     | 0   | 0.123| 0.031| 8             |
| C9| 0     | 0   | 0.227| 0.059| 7             |
| C10| 0   | 0   | 0.423| 0.109| 3             |

CR<0.1
It can be seen from Table 5 that the weights of B1, B2, and B3 are 0.413, 0.327, and 0.260, respectively, indicating the importance of the three: Environmental Benefits> Economic Benefits> Technical Performance. In the environmental benefit criterion layer, the weights of C1, C2, and C3 are: 0.250, 0.500, and 0.250, indicating that the "Salt removal rate" indicator is the most important, and the "COD removal rate" and "SS removal rate" indicators are next most important. In the economic benefit criterion layer, the weights of C4, C5, and C6 are: 0.240, 0.549, and 0.210, indicating that the "Difficulty and ease of operation management" indicator is the most important, the "Difficulty and ease of infrastructure" indicator is secondarily important, and the "Wastewater reuse rate" indicator is important. In the technical performance criterion layer, the weights of C7, C8, C9, and C10 are: 0.227, 0.123, 0.227, and 0.423, respectively, indicating that the "Technology maturity" index is the most important, "Difficulty and ease of infrastructure" and "Incoming water quality requirements" are important. The importance of the index is second, and the "Difficulty and ease of operation management" is the last.

The hierarchical total ranking results show that the order of importance of the evaluation index system for the advanced treatment technology of printing and dyeing wastewater is: C2>C5>C10>C1=C3>C4>C6=C7=C9>C8. That is, the "salt removal rate" has the most influence in the "industrial evaluation index for advanced treatment of printing and dyeing wastewater", followed by "Difficulty and ease of operation management", "Technology maturity" ranked third, "COD removal rate" and "SS removal rate". The overall ranking of the rate indicator is of equal importance, both of which are fourth. The weights of other indicators are all less than 0.1. The two indicators that have the least impact on the "Dyeing and printing wastewater advanced treatment technology evaluation" are "Incoming water quality requirements" and "Difficulty and ease of operation management", whose weights are 0.059 and 0.031, respectively.

4. Conclusion

With the shortage of water resources in our country, the improvement of the technological level of the textile industry and the increase in the added value of products, the combination of different advanced wastewater treatment technologies will also become an important development direction. The research conclusions of this paper are as follows:

(1) The 10 evaluation indicators for the evaluation of the advanced treatment technology of printing and dyeing wastewater in industrial parks reflect the environmental benefits, economic benefits, and technical performance of the advanced treatment technology of printing and dyeing wastewater. They are representative and comprehensive.

(2) The weighting value of the evaluation index of advanced treatment technology of printing and dyeing wastewater calculated by AHP is more accurate and credible. Hierarchical single ranking results show that the order of importance of the criteria layer is: environmental benefits> economic benefits> technical performance, and the weights of the three are 0.250, 0.500, and 0.250.

(3) The hierarchical total ranking results show that the importance ranking of the 10 evaluation indicators constructed is as follows: Salt removal rate>Difficulty and ease of operation management> Technology maturity> COD removal rate = SS removal rate>Capital investment costs>Wastewater reuse rate>Difficulty and ease of infrastructure=Incoming water quality requirements>Difficulty and ease of operation and management. Its weights are: 0.206, 0.179, 0.109, 0.103, 0.078, 0.068, 0.059, 0.059, 0.031.

(4) Analytic hierarchy process is used to comprehensively evaluate the advanced treatment technology of printing and dyeing wastewater, and the qualitative indicators are quantified according to the scores of experts. Finally, the scores of each technology are calculated, which provides a basis for printing and dyeing companies to choose the appropriate treatment technology. Combining the company's own situation and the characteristics of the discharged wastewater, choosing the best treatment technology can not only save the company's funds and improve the wastewater treatment effect, but also reuse the wastewater, save water resources, and take a sustainable development path.
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