Research on Rural Wastewater Treatment Evaluation System Based on AHP Method

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Abstract. Based on Analytic Hierarchy Process (AHP), this paper analyzes the current situation of rural wastewater treatment in China, and constructs China's wastewater treatment evaluation system from four aspects: technical factors, economic factors, social factors and environmental factors. According to the actual situation of rural wastewater treatment in China, combined with the scoring of experts on the wastewater treatment evaluation system, Calculating the indicator weights shows that environmental factors account for the largest proportion, and the core elements of environmental factors are aesthetics, and policy factors and initial construction costs are more important in economic factors. These data will provide reference for the establishment of rural wastewater treatment evaluation indicators in the future.

Key words: Rural, Wastewater Treatment, Evaluating index system, AHP.

1. Introduction
With the rapid development of China's economy, China's rural wastewater treatment is facing severe challenges. China's rural areas emit about 15 billion m$^3$ of wastewater per year, but the wastewater treatment rate is very low. According to the "13th Five-Year Plan for Comprehensive Improvement of Rural Environment", only 22% of the domestic wastewater in the built villages in China has been treated. In the process of rural economic development, the issue of environmental governance has been neglected, especially the rural wastewater treatment, which not only does not conform to the principle of sustainable development in China, but also restricts the future development of the rural economy. Therefore, the construction of a reasonable rural wastewater treatment evaluation system is the fundamental guarantee for the quality of rural wastewater treatment. This paper uses AHP to explore the construction of China's rural wastewater treatment evaluation system, which can provide important reference for government managers, engineers and other stakeholders in rural wastewater treatment.

2. Problems existing in rural wastewater treatment
Rural wastewater refers to the wastewater generated by the living activities of rural residents. The main characteristics of rural wastewater are characterized by complex composition, relatively low concentration of various pollutants, basically no or a small amount of heavy metals and toxic and harmful substances, strong biochemical property; large variation coefficient of drainage; wide and scattered pollution.
The problems existing in the treatment of rural wastewater in China are mainly due to the imperfect laws and regulations on the treatment of rural domestic wastewater in China. So far, there are many problems concerning the treatment of rural domestic wastewater, such as: compulsory laws and regulations are few; the economy in rural areas of China is relatively backward, there is no long-term stable funds for the operation and maintenance of facilities; the degree of education of farmers is higher. Low, lack of environmental awareness and other issues.

3. Main influencing factors affecting rural wastewater treatment

According to the field investigation of rural wastewater treatment, it is understood that the construction of rural wastewater treatment evaluation index system mainly involves economic, technical, environmental and social factors:

1. Economic factors

   In the process of rural wastewater treatment, economic factors determine the extent of rural wastewater treatment. The feasibility of rural wastewater treatment construction projects is greatly affected by economic factors, but most of the rural wastewater treatment has public product attributes. Therefore, rural wastewater treatment can not produce direct economic benefits, and can only determine the benefits by analyzing economic conditions.

2. Technical factors

   To evaluate the effect of rural wastewater treatment, technical factors play a direct role. The effect of rural wastewater treatment is closely related to the treatment technology. However, due to the difference between urban and rural wastewater, urban wastewater treatment technology and industrial wastewater treatment technology cannot be directly applied to rural wastewater treatment. Therefore, rural wastewater treatment technology has relative independence and regularity.

3. Environmental factors

   Rural wastewater treatment can not directly produce economic benefits, and its treatment effect is mainly reflected in environmental factors, so environmental factors are fundamental to rural wastewater treatment. In rural wastewater treatment system, environmental factors are usually considered, not only considering the impact of the construction and operation of the wastewater treatment project on the environment, but also analyzing whether the project can benefit from resource utilization.

4. Social factors

   Rural wastewater treatment will produce certain social benefits, which is also an important factor to be considered in the treatment of rural wastewater systems, and should also be used as one of the evaluation indicators. The construction of rural wastewater treatment depends not only on the cost of the operation phase, but also on the contribution of the project to the society, such as the impact on the development of the environmental protection industry, the impact on the construction of the new countryside, the impact on the harmonious society, etc.

4. Establishment of Evaluation Index System for Rural wastewater Treatment

Systematic treatment of rural wastewater involves economic, technological, environmental and social factors. Therefore, the AHP method is used to divide the evaluation index system into three levels: target layer, criterion layer and indicator layer.

According to the application of analytic hierarchy process in rural wastewater treatment, combined with the actual situation of rural wastewater treatment, this paper screens out the factors that may affect the rural wastewater treatment, and then the characteristics of each influencing factor according to economy, technology, The social and environmental aspects are classified into four levels and placed in the corresponding criteria layer, as shown in Table 1;
Table 1. Indicators of Rural wastewater Treatment

| Target layer               | Criteria layer | Indicator layer                                      |
|----------------------------|----------------|-----------------------------------------------------|
| Rural wastewater Treatment(A) | Economic factors (B1) | C1: Team building<br>C2: Residents' willingness to pay<br>C3: Maintenance management costs<br>C4: Initial construction costs<br>C5: Policy factors |
|                            | Technical factors (B2) | C6: Specialization level<br>C7: Water quality compliance rate<br>C8: Treatment of wastewater volume<br>C9: Annual operating rate<br>C10: Quality of construction construction |
|                            | Environmental factors (B3) | C11: Residents' awareness of water saving<br>C12: Residents' awareness of environmental protection<br>C13: Aesthetics<br>C14: Resource regeneration |
|                            | Social factors (B4) | C15: Number of people per unit area<br>C16: Sustainable development<br>C17: Development of environmental protection industry<br>C18: Life satisfaction |

5. AHP method for evaluation of rural wastewater control index system

The Analytic Hierarchy Process (AHP) was developed by Professor T.L. Saaty around 1970 to develop an operational research method that can simultaneously use both qualitative and quantitative analysis.

The use of AHP is divided into the following four steps:

1. Establish a judgment matrix. Assuming that the impact indicator A is related to the lower level sub-item indicators B₁, B₂, ..., Bᵢ, a judgment matrix can be constructed. Then invite the experts to compare the importance of each indicator in the hierarchy, and fill in the comparison result value into the judgment matrix.

2. Perform mathematical operations on the obtained judgment matrix. Normalize each column element in the matrix, normalize the vector, and finally obtain the maximum eigenvalue \( \lambda_{\text{max}} \) of the matrix matrix by formula \( \lambda_{\text{max}} = \sum_{i=1}^{n} \frac{(AW)_i}{nW_i} \).

3. Consistency test. The judgment matrix must pass the consistency test, otherwise the matrix error is unacceptable and the result of the matrix operation is not reliable. The consistency test of the judgment matrix is performed by calculating the consistency index CI=(\( \lambda_{\text{max}} - n \))/(n-1). If the consistency ratio CR=CI/RI<0.1, the judgment matrix is acceptable, and the normalized feature vector is equal to the value of the weights vector.

4. The total order of the levels. To calculate the composite weights of each layer element on the system target, and perform a total sort to determine the importance of the lowest level elements in the hierarchy in the overall target.

According to the AHP method, the weight of the evaluation index of rural wastewater treatment is determined, and the weight of each index is determined by the analytic hierarchy process. The weight results are shown in Table 2, Table 3, Table 4, Table 5, and Table 6.
Table 2. Economic factor evaluation index weight result

|    | C1  | C2  | C3  | C4  | C5  | Weights |
|----|-----|-----|-----|-----|-----|---------|
| C1 | 1   | 1/2 | 1/3 | 1/3 | 1/4 | 0.076   |
| C2 | 2   | 1   | 1   | 1/2 | 1/2 | 0.153   |
| C3 | 3   | 1   | 1   | 1   | 1/3 | 0.176   |
| C4 | 3   | 2   | 1   | 1   | 1/2 | 0.218   |
| C5 | 4   | 2   | 3   | 2   | 1   | 0.378   |

From Table 2: $\lambda_{\text{max}} = 5.095$, CI=0.024, RI=1.12, CR=0.021<0.1

Table 3. Technical factor evaluation index weight result

|    | C6  | C7  | C8  | C9  | C10 | Weights |
|----|-----|-----|-----|-----|-----|---------|
| C6 | 1   | 1   | 1/3 | 3   | 1   | 0.172   |
| C7 | 1   | 1   | 1/3 | 3   | 3   | 0.216   |
| C8 | 3   | 3   | 1   | 4   | 4   | 0.467   |
| C9 | 1/3 | 1/3 | 1/4 | 1   | 1   | 0.084   |
| C10| 1   | 1/3 | 1/4 | 1   | 1   | 0.106   |

From Table 3: $\lambda_{\text{max}} = 5.181$, CI=0.045, RI=1.12, CR=0.04<0.1

Table 4. Environmental factor evaluation index weight result

|    | C11 | C12 | C13 | C14 | Weights |
|----|-----|-----|-----|-----|---------|
| C11| 1   | 1/4 | 1/3 | 1/4 | 0.079   |
| C12| 4   | 1   | 1/3 | 1/2 | 0.189   |
| C13| 3   | 3   | 1   | 1   | 0.355   |
| C14| 4   | 2   | 1   | 1   | 0.348   |

From Table 4: $\lambda_{\text{max}} = 4.169$, CI=0.056, RI=0.89, CR=0.062<0.1

Table 5. Social factor evaluation index weight result

|    | C11 | C12 | C13 | C14 | Weights |
|----|-----|-----|-----|-----|---------|
| C11| 1   | 3   | 3   | 4   | 0.499   |
| C12| 1/3 | 1   | 1   | 3   | 0.206   |
| C13| 1/3 | 1   | 1   | 1   | 0.157   |
| C14| 1/4 | 1/3 | 1   | 1   | 0.113   |

From Table 5: $\lambda_{\text{max}} = 4.123$, CI=0.041, RI=0.89, CR=0.046<0.1

Table 6. Criteria layer evaluation index weight result

|    | B1  | B2  | B3  | B4  | Weights |
|----|-----|-----|-----|-----|---------|
| B1 | 1   | 4   | 1/2 | 3   | 0.308   |
| B2 | 1/4 | 1   | 1/4 | 1/3 | 0.077   |
| B3 | 2   | 4   | 1   | 4   | 0.473   |
| B4 | 1/3 | 3   | 1/4 | 1   | 0.142   |

From Table 6: $\lambda_{\text{max}} = 4.159$, CI=0.053, RI=0.89, CR=0.06<0.1

The overall consistency is:

$$CI = \sum_{i=1}^{4} B_{i} \cdot CI_{i} = 0.0432; RI = \sum_{i=1}^{4} B_{i} \cdot RI_{i} = 0.9791; CR = \frac{CI}{RI} = 0.044 < 0.1$$
The above analysis shows that the single-sorted structure of each level has satisfactory consistency, and the overall ranking also has satisfactory consistency. From this, the specific scores of the various criteria and indicators in the rural wastewater treatment evaluation index system are obtained. As shown in Table 7.

Table 7. Criteria layer and indicator level indicator scores

| Target layer / Proportion | Criteria layer / Proportion | Indicator layer / Proportion |
|--------------------------|-----------------------------|-----------------------------|
|                          |                             | C1/2%                       |
|                          |                             | C2/5%                       |
| B1/31%                   |                             | C3/5%                       |
|                          |                             | C4/7%                       |
|                          |                             | C5/12%                      |
|                          |                             | C6/1%                       |
|                          |                             | C7/2%                       |
| B2/8%                    |                             | C8/4%                       |
|                          |                             | C9/1%                       |
|                          |                             | C10/1%                      |
|                          |                             | C11/4%                      |
|                          |                             | C12/9%                      |
| A/100%                   |                             | C13/17%                     |
| B3/47%                   |                             | C14/16%                     |
|                          |                             | C15/7%                      |
|                          |                             | C16/3%                      |
| B4/14%                   |                             | C17/2%                      |
|                          |                             | C18/2%                      |

From the final weight division of the evaluation index system, we can see that ‘Environmental factors B3’ and ‘Economic factors B1’ play a dominant role in the evaluation, accounting for 47% and 31% of the criteria layer respectively.

‘Aesthetics C13’ is the core element of environmental factors, and C13 accounts for 17% of the indicator layer, indicating that the impact of rural wastewater discharge on the environment is huge. ‘Resource regeneration C14’ accounting for 16% of the indicator layer, indicating whether the wastewater can be converted into resource recycling after treatment is one of the important indicators to consider environmental factors.

Among the economic factors, ‘Initial construction cost C4’ and ‘Policy factor C5’ are important determinants. Because rural wastewater treatment must first consider the promotion and construction of the government, and then discuss the maintenance and management issues.

Technical factors accounted for 8% of the Criteria layer, reflecting the lack of technical demand for rural wastewater treatment systems.

Among the social factors, ‘the number of people per unit area C15’ accounts for 7% of the indicator level, indicating that the fundamental purpose of the establishment of the rural wastewater treatment system is to solve the needs of more villagers.

6. Conclusion

This paper uses AHP method to construct a rural wastewater treatment evaluation index system based on the actual situation of rural wastewater treatment in China, which is divided into four indicators: economic factors, technical factors, environmental factors and social factors, and their corresponding 18 indicators. And the corresponding index weights are determined, which can provide reference for the relevant parties in rural wastewater treatment.
References

[1] Lingfang Zeng, Brief comment on new methods of rural domestic wastewater treatment abroad [J], China Rural Water and Hydropower, 2001(09):30-31+33.

[2] Hongyang SU, Present situation of decentralized domestic wastewater treatment technology in Chinese villages and towns [J], Water & Wastewater Engineering, 2015, 51(S1):197-201.

[3] Tiejian Zhang, Xiaoyan Zhang, Screening of rural domestic wastewater treatment technology in Hebei plain area based on AHP [J], Acta Agriculturae Zhejiangensis, 2015, 27 (06): 1037-1041.

[4] Lujun Chen, Reflections on decentralized wastewater treatment technologies and policies in rural areas of China [J], Environmental Protection, 2014, 42(15):30-33.