Analysis of Safety Factors of Urban Sewage Treatment Plant Based on AHP Method

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Abstract. In the process of social and economic development, the process of urbanization is also accelerating. Environmental engineering has become an important task to ensure the urban environment and the quality of people's living and living, and is also a key link to achieve urban layout optimization. Due to the late start of environmental engineering in China, there are still many problems to be solved. Based on China's actual national conditions, this paper classifies the identified security risks and builds a safety evaluation index system for urban sewage treatment plants. Finally, the analytic hierarchy process is used to construct the importance model of security risk factors, and the importance ranking of the main security risk factors is obtained.

Key words: Sewage treatment plant, Security risk analysis, AHP.

1. Introduction
The understanding of security risks generally begins with the most intuitive feelings of everyone. Floods, storms, mudslides, etc. that occur in nature cause events that seriously affect the consequences of the hazard, which are often considered objective dangers. Their basic characteristics can be summarized as the loss of the outcome of future things is uncertain [1]. For the safety of sewage treatment plants, the risk term refers to the probability that the main body of the project will deviate from the expected result of the future decision-making and actual results. The main characteristics of risk are reflected in two aspects. The first point is the actual probability of what happened, and the second is the degree of corresponding damage caused to the project after the risk occurs [2].

2. Urban sewage treatment plant safety risk identification and classification
The prerequisite for safety risk response is the identification and classification of urban sewage plant risks, and the identified risks are classified in the process of risk identification. The risk classification method will also affect the risk identification process. Therefore, the risk identification process and risk classification methods of urban sewage plants should be integrated [3, 4]. Through literature review and data collection, the safety factors affecting urban sewage plants are divided into three aspects:
   - Equipment facility factors. Unreasonable road width in the plant area causes traffic accidents; the fire separation distance of flammable and explosive materials or buildings is not enough, and fire and explosion accidents are prone to occur; the entrance and exit of the building and structure are unreasonable, which makes evacuation difficult. Incorrect installation of mechanical equipment may affect the normal operation of the sewage treatment process; no accidental emission protection facilities
are installed, causing environmental pollution; mechanical dehydration, there are dangers of object impact, mechanical injury, lifting injury, etc. The sludge emits odor and causes dizziness, nausea and poisoning suffocation; chlorine gas cylinders, chlorination machines and connecting pipelines used for disinfection may malfunction, causing poisoning accidents.

Environmental factors. Poor operating conditions such as high temperatures, noise, vibration, non-ionizing radiation, etc, may cause occupational hazards. Working under strong noise for a long time can cause deafness, and mechanical vibration can cause damage to components. Various natural disasters, such as earthquakes, can damage structures and cause pollution from sewage overflow.

Management factors. The failure of the safety production management organization and the imperfect rules and regulations are important reasons for the accident. Improving the management organization, improving the safety production rules and regulations, strengthening safety education and training, and eliminating illegal operations are important links to prevent accidents.

3. Establishment of Safety Risk Assessment Index System for Urban Sewage Treatment Plants

Establishing a sound evaluation index system is conducive to comprehensive evaluation of multi-level indicators. The urban sewage treatment plant safety risk assessment index system is to break down the more complex risk factors in the project into simple basic units that are easy to identify, thus constructing a set of scientific and practical safety risk assessment index system [5].

| Target layer                              | Criteria layer                                                                 |
|-------------------------------------------|------------------------------------------------------------------------------|
| Sewage treatment plant safety (A)         | C1: building                                                                  |
| Equipment facility factors (B1)           | C2: Production equipment and process facilities                               |
|                                          | C3: Special equipment and pressure vessels                                   |
|                                          | C4: Power supply and pressure vessel                                         |
| Environmental factors (B2)                | C5: Socioeconomic environment                                                 |
|                                          | C6: Working environment                                                       |
|                                          | C7: Natural environment                                                       |
|                                          | C8: Water quality and quantity                                                |
| Management factors (B3)                   | C9: organization                                                              |
|                                          | C10: Rules and regulations                                                    |
|                                          | C11: Safety investment                                                        |
|                                          | C12: manager                                                                  |

4. AHP method for safety risk assessment of urban sewage treatment plants

4.1. Construction of Judgment Matrix of Criteria Layer B

The construction of the judgment matrix of this criterion layer not only uses the questionnaire method to collect data, but also uses the literature review related methods. From the existing literature, it is concluded that the safety risk assessment of various different types of urban sewage treatment plants
has been studied by experts and scholars. The questionnaire was issued by the relevant personnel, and then the data was obtained according to the weighted average of the above matrix value table (Table 1).

The calculation process is as follows, the environmental factor (B2) is compared with the equipment facility factor (B1). 2 people think it is just as important (value 1), 7 people think that the market level is slightly important, 10 people think it is obviously important, 4 people think it is more important, 2 people think it is especially important. Therefore the weighted average is calculated:

\[ B_{21} = \frac{2 \times 1 + 7 \times 2 + 10 \times 3 + 4 \times 4 + 2 \times 5}{24} = 3 \]

\[ B_{12} = \frac{1}{B_{21}} = 0.3333 \]

From the above, after processing all the data, the other elements of the equipment facility factor, the environmental factor, and the management factor security risk (A-Bi) judgment matrix and the data are shown in Table 2.

**Table 2. Safety Risk Importance A-Bi Judgment Matrix**

| A   | B1   | B2   | B3   |
|-----|------|------|------|
| B1  | 1    | 0.3333 | 0.2512 |
| B2  | 3    | 1    | 0.5   |
| B3  | 3.98 | 2    | 1     |

4.2. **Criteria layer Ci judgment matrix**

The judgment matrices of each criterion layer Ci are shown in Tables 3, 4, and 5, respectively:

**Table 3. Environmental factor safety risk importance judgment matrix**

| B   | C11  | C12  | C13  | C14  |
|-----|------|------|------|------|
| C11 | 1    | 0.7692 | 0.5556 | 0.4167 |
| C12 | 1.3  | 1    | 0.5263 | 0.4   |
| C13 | 1.8  | 1.9  | 1    | 0.5882 |
| C14 | 2.4  | 2.5  | 1.7  | 1    |

**Table 4. Environmental factors safety risk importance judgment matrix**

| B   | C21  | C22  | C23  | C24  |
|-----|------|------|------|------|
| C21 | 1    | 0.6667 | 0.4  | 0.2941 |
| C22 | 1.5  | 1    | 0.5882 | 0.4167 |
| C23 | 2.5  | 1.7  | 1    | 0.5405 |
| C24 | 3.4  | 2.4  | 1.85 | 1    |

**Table 5. Management factors Security risk importance judgment matrix**

| B   | C31  | C32  | C33  | C34  |
|-----|------|------|------|------|
| C31 | 1    | 0.7142 | 0.4166 | 0.3571 |
| C32 | 1.4  | 1    | 0.625 | 0.3703 |
| C33 | 2.4  | 1.6  | 1    | 0.6667 |
| C34 | 2.8  | 2.7  | 1.5  | 1    |
4.3. Calculation of Single Sorting Weight Vector and Consistency Test of Judgment Matrix

According to the basic calculation steps of the single sort vector above, the calculation process is as follows (taking the single sort vector of the Ai-B judgment matrix as an example):

1. Judging the product of each row of elements of the matrix:
   \[
   D_1 = \prod_{j=1}^{i} B_{ij} = B_{11} \times B_{12} \times B_{13} = 1 \times 0.3333 \times 0.2512 = 0.0834
   \]
   Similarly, \(D_2=1.5\), \(D_3=8\);

2. Calculate the nth root of the product of each row element of the judgment matrix:
   \[
   d_i = \sqrt[3]{D_i} = 0.4369, \ d_2=1.1447, \ d_3=2;
   \]

3. Normalize the vector
   \[
   W_i = \frac{d_i}{\sum_{i=1}^{3} d_i}
   \]
   Then the single sort vector of Ai-B is:
   \[
   W_{A-B_1} = \begin{bmatrix} 0.1219 & 0.3196 & 0.5584 \end{bmatrix};
   \]

4. Calculate the maximum eigenvalue of the judgment matrix:
   \[
   \lambda_{\max} = \begin{bmatrix} B_{11}W_1 + B_{12}W_2 + B_{13}W_3 \\ B_{21}W_1 + B_{22}W_2 + B_{23}W_3 \\ B_{31}W_1 + B_{32}W_2 + B_{33}W_3 \end{bmatrix}
   \]
   Substituting data to obtain: \(\lambda_{\max}=3.0245\);

5. Consistency index CI calculation:
   \[
   \lambda_{\max} - 3 \]
   \[
   \sum_{i=1}^{3} \frac{d_i}{3-1} = 0.0086;
   \]

6. Judgment matrix consistency test, \(RI=0.58\), \(CR = \frac{CI}{RI} = 0.0167 < 0.1\), A-Bi judgment matrix conforms to consistency test.

Perform the above steps again, the single order weight vector of the equipment facility factor judgment matrix (B1-C1) is:
   \[
   W_{B_1-C_1} = \begin{bmatrix} 0.1473 & 0.1651 & 0.2761 & 0.4147 \end{bmatrix}, \lambda_{\max}=4.0161, \ CR=0.0024<0.1, \text{compliance with the consistency test.}
   \]

The single-order weight vector of the environmental factor judgment matrix (B2-C2) is:
   \[
   W_{B_2-C_2} = \begin{bmatrix} 0.1190 & 0.1706 & 0.2754 & 0.4343 \end{bmatrix}, \lambda_{\max}=4.0103, \ CR=0.0383<0.1, \text{compliance with the consistency test.}
   \]

The single-order weight vector of the management factor judgment matrix (B3-C3) is:
   \[
   W_{B_3-C_3} = \begin{bmatrix} 0.1212 & 0.1716 & 0.2742 & 0.4263 \end{bmatrix}, \lambda_{\max}=4.0269, \ CR=0.0096<0.1, \text{compliance with the consistency test.}
   \]

4.4. Calculate the total sort weight vector and do a consistency check

Calculate the comprehensive weights of the risk factors of the criterion layer on the safety risk assessment of the sewage treatment plant, and establish a weight set.

\[
W_0 = W_C \times W_{A-B} = (0.0178 \ 0.0184 \ 0.0622 \ 0.0586 \ 0.0367 \ 0.0533 \ 0.0897 \ 0.1288 \ 0.0659 \ 0.0976 \ 0.1525 \ 0.2283)
\]

The hierarchical total order consistency check is as follows:

\[
CI = \sum_{i=1}^{3} B_i C_{i=1}^{(0)} + B_1 C_{i=1}^{(1)} + B_2 C_{i=1}^{(2)} + B_3 C_{i=1}^{(3)} = 0.12 \times 0.0024 + 0.3196 \times 0.0035 + 0.5584 \times 0.0494 = 0.0287
\]
RI = \sum_{i=1}^{3} B_iRI^{(i)} = B_1RI^{(1)} + B_2RI^{(2)} + B_3RI^{(3)} = 0.122 \times 0.58 + 0.3196 \times 0.9 + 0.5584 \times 0.9 = 0.8602

CR = \frac{CI}{RI} = 0.0367 < 0.1, \text{ compliance with the consistency test.}

5. Conclusion
This chapter mainly uses the analytic hierarchy process to assess the importance of safety risk factors in urban sewage treatment plants in China. The basic model is constructed by using the analytic hierarchy process, and the importance level of the target level risk is obtained through sorting and mathematical operations. The order of importance from large to small is management, equipment and facilities, and environmental safety risks; it can basically reflect the actual situation of the safety capacity of the sewage treatment plant. For the total ranking weights of the 12 risk factors in the whole system security risk indicator layer, the order of importance of the 12 major categories of major risk factors is: management personnel, water quality and quantity, safety inputs, regulatory mapping, power distribution and lightning protection systems, natural environment, operating environment, special equipment and pressure vessels, organization, production equipment and process facilities, buildings, socio-economic environment. Generally speaking, human factors are the primary factors. Therefore, the most effective way to reduce accidents is to improve people's quality and improve management systems.

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