Research on Comprehensive Evaluation of Water Ecological Environment in Small Basin

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Abstract. In order to evaluate the water ecological environment quality of small basin and realize scientific management and control of small basin, 15 sampling spots were set up on the small basin of Nanhe River of Qionglai city, 11 indexes were selected from three aspects of water environmental quality, aquatic ecology and aquatic habitat for each sampling spot, and the grey relational analysis (GRA) was used to comprehensively evaluate the water ecological environment quality in the small watershed of Nanhe River of Qionglai city. The results show that it is feasible to use GRA to comprehensively evaluate the regional water ecological environment. The water ecological environment of Wenjing River, Baimo River and Dengjiang River is in good condition, and their control standards should be relatively improved. The water ecological environment of the five reaches of Xiaonan River, Shitou River, Pujiang River, Inclined River and the lower reaches of Nanhe River is in poor condition, which requires priority control. Pollution prevention and control measures should be considered comprehensively in combination with the ecological environmental pressure borne by the reach.

1. Introduction

With the rapid development of economy in the region where the small watershed is located, the problem of water ecological environment in the small watershed becomes more and more serious. From the perspective of sustainable social development in the region where the small watershed is located, it is imperative to analyse the present situation of water ecological environment of small watershed, master the relationship between water ecological environment of small watershed and human activities, and explore the important influence indexes that affect the water ecological environment of small watershed, it can also provide sufficient theoretical basis for policy makers. At present, scholars at home and abroad focus on the comprehensive evaluation of watershed water ecological environment mainly on the single evaluation and pair evaluation among water environmental quality, ecological environmental quality and biological indicator species. Few of the three methods have been used to comprehensively evaluate the water ecological environment in small watershed. Grey Relational Analysis (GRA) is an evaluation method widely used in various fields [1], and few reports have been reported on the comprehensive evaluation of water ecological environment in small watershed by choosing this method. Taking the Nanhe small watershed in Denglai as an example, this paper makes a comprehensive evaluation on the water environment quality, aquatic ecological environment quality and biological indicator species. Few of the three methods have been used to comprehensively evaluate the water ecological environment in small watershed. Grey Relational Analysis (GRA) is an evaluation method widely used in various fields [1], and few reports have been reported on the comprehensive evaluation of water ecological environment in small watershed by choosing this method. Taking the Nanhe small watershed in Denglai as an example, this paper makes a comprehensive evaluation on the water environment quality, aquatic ecological environment quality and biological indicator species. Few of the three methods have been used to comprehensively evaluate the water ecological environment in small watershed.
2. Materials and Methods

2.1. Overview of the study area

Nanhe small watershed (Qionglai section) is located in Qionglai City, southwest of Chengdu Plain. It is between 102°54’~104°53’e and 30°05’~31°26’n. It originates from Tiantai Mountain and Zhenxi mountain in the southwest of Qionglai city. There are two tributaries in the upper source, Wenjing River on the left and Baimo River on the right. It is called Nanhe after the river at Qikou of Shuikou Town. The tributaries on the left bank of Nanhe River mainly include the outflow River and xiejiang River from Dayi County and the Xiaonan river formed by drainage and irrigation. The tributaries on the right bank are mainly Pujiang River from Pujiang County.

2.2. Sample collection and data process

2.2.1. Sample collection.

According to the environmental pressure and socio-economic situation in the small watershed, combined with the basic geographic information data such as altitude, river system, administrative division, etc., 15 sampling points were selected in the Nanhe small watershed (Qionglai section), with the number of S1-S15. Aquatic organisms and water quality were sampled at 15 sampling points (S1 ~ S15).

2.2.2. Biodiversity index.

According to the sampling results of phytoplankton and zooplankton in aquatic organisms, the Shannon—Weiner index model is selected to analyze the biodiversity of phytoplankton, zooplankton and benthos. The calculation model is as follows, and the analysis and calculation are completed in past3.0.

\[ H = -\sum \left( \frac{n_i}{N} \right) \ln \left( \frac{n_i}{N} \right) \]  

Where: \( n_i \) — the number of individuals of the ith species  
N — the total number of individuals of all species in the community  
Shannon—Weiner index evaluation criteria [2] are shown in Table 1.

| Shannon—Weiner value | <1 | 1~2 | 2~3 | >3 |
|----------------------|----|-----|-----|----|
| Water quality grade  | Heavy pollution | Heavy medium pollution | Light to moderate pollution | Mild or no pollution |

2.2.3. Water habitat analysis.

In this paper, five indicators including habitat complexity, river water quantity, vegetation diversity, human activity intensity and riparian land use type were selected to evaluate the water habitat of Nanhe small watershed (Qionglai section). The evaluation criteria are shown in Table 2.

| Evaluation index | Good (16~20) | Preferably (11~15) | Commonly (6~10) | Difference (0~5) |
|------------------|--------------|--------------------|----------------|------------------|
| 1 Habitat complexity | There are aquatic vegetation, litter, inverted technique, inverted concave bank and boulder and other small habitats | There are aquatic vegetation, litter and concave bank and other small habitat | It is dominated by one or two kinds of microhabitats | It is dominated by one kind of microhabitat, and the sediment is mainly silt or fine sand |
2.2.4. Data normalization.
In general, all indicators can be divided into reverse indicators and positive indicators [3].
A positive indicator is an indicator whose value is greater than the value of the index. Its normalization method is:

$$X_{ij} = \frac{x_{ij} - x_{jmin}}{x_{jmax} - x_{jmin}}$$  \hspace{1cm} (2)

A negative indicator is an indicator whose value is as small as possible and whose normalization method:

$$X_{ij} = 1 - \frac{x_{ij} - x_{jmin}}{x_{jmax} - x_{jmin}}$$  \hspace{1cm} (3)

2.2.5. Grey correlation analysis.
There are n objects, each object has m items, the Evaluation Index data is normalized, the normalized data is x₁, x₂, ..., xₘ=[x₁(1), x₂(2), ..., xₘ(n)]. i=1, 2, ..., m. Let x₀ be the comparison sequence, then x₀ and xᵢ's Correlation Coefficient for the k element [4] is:

| River water quantity | The amount of water is large, the river is submerged to the bank, or only a small amount of river channel is exposed | The water volume is relatively large, and the river submerges about 75% of the river course | The amount of water is normal, and the river submerges 25% - 75% of the river channels | The water is very small and the river is dry |
|----------------------|----------------------------------------------------------------------------------------------------------------------------------|---------------------------------------------------------------------------------|-------------------------------------------------------------------------------------------------|----------------------------------------------------------------------------------------------------------------------------------|
| Vegetation diversity | There are many kinds of vegetation around the river bank. More than 50% of the embankment is covered with vegetation | There are many kinds of vegetation around the river bank, but the accumulation is general. 50% - 25% of the embankments are covered with vegetation | The species of vegetation around the river bank is relatively small, but the volume is small. Less than 25% of the embankment is covered with vegetation | There is little vegetation around the river bank. No embankment cover, no vegetation |
| Intensity of human activity | There is no interference or little human activity | Human interference is small, with a small number of pedestrians or bicycles passing through | Human interference is large, and a small number of motor vehicles pass through | Human interference is very big, the only way to traffic, often through the motor vehicles |
| Riparian land use types | There is no cultivated soil on both sides of the river bank, so it is rich in nutrition | There is no cultivated soil on one side of the river bank and cultivated soil on the other side | To cultivate the soil on both sides of the river bank, chemical fertilizers and pesticides should be applied | On both sides of the river bank are exposed weathered soil layers abandoned by cultivation, with few nutrients |
\[ \zeta_i(k) = \frac{\Delta \min + \rho \Delta \max}{\Delta_i + \rho \Delta \max}, i=1,2,\ldots,n; k=1,2,\ldots,m \] (4)

\[ \Delta \min = \min_i \{\min_k [x_0(k) - x_i(k)]\} \] (5)

\[ \Delta \max = \max_i \{\max_k [x_0(k) - x_i(k)]\} \] (6)

In the formula: for the resolution factor, the value interval is [0,1]
The correlation between the first reference sequence and the comparison sequence is:

\[ \gamma_i = \frac{1}{n} \sum_{k=i}^{n} \zeta_i(k) \] (7)

\( \gamma_i \) is the degree of association of the i reference sequence.

3. Results & Discussion

3.1. Determination of evaluation index
The comprehensive evaluation index system is shown in Table 3.

Tab 3. Comprehensive evaluation index system of water ecological environment in small basin of Nanhe river.

| General evaluation | Evaluation Subsystem Evaluation | Evaluating indicator | Standard value |
|--------------------|---------------------------------|----------------------|----------------|
| A                   | Evaluation of regional water environment quality | Chemical oxygen demand concentration A1 | 15 |
|                    |                                  | Ammonia concentration A2 | 0.15 |
|                    |                                  | Total phosphorus concentration A3 | 0.02 |
| B                   | Evaluation of regional aquatic ecological quality | Phytoplankton Diversity Index B1 | 3 |
|                    |                                  | Zooplankton diversity index B2 | 3 |
|                    |                                  | Macrobenthic diversity index A3 | |
| C                   | Evaluation of Regional Aquatic Habitat Quality | Habitat complexity C1 | 20 |
|                    |                                  | River water condition C2 | 20 |
|                    |                                  | Vegetation diversity C3 | 20 |
|                    |                                  | Human activity intensity C4 | 20 |
|                    |                                  | Riparian land use type C5 | 20 |

3.2. Calculation of correlation coefficient and correlation degree
After dimensionless treatment of comparison sequence and reference sequence, the correlation coefficient and correlation degree are calculated by formula (4) ~ (7), in which the resolution coefficient is 0.5 [5], the weight of each index is treated with equal weight, and the gray correlation coefficient matrix can be calculated by formula (4) ~ (6).
According to formula (7), the grey correlation degree is (0.8107, 0.6213, 0.6454, 0.6186, 0.4570, 0.6403, 0.5926, 0.6024, 0.6173, 0.5483, 0.5077, 0.4071, 0.5091, 0.5447, 0.5704). The order of correlation degree of each sampling point is shown in Figure 1.

According to the sequence of grey correlation degree of each sampling point in Nanhe small watershed, the ecological environment of Wenjing River, Baimo River and Chujiang river is good, and the highest correlation degree of the upper reaches of Wenjing river is 0.8107. The reason is that Wenjing River and Baimo River are the source rivers of Qionglai water system. They are under the pressure of ecological environment together with the outflow rivers. Compared with other river sections, the human activities are relatively low. Most of the river sections still retain the natural river morphology and the ecological functions are relatively sound.

However, the water ecological environment of Xiaonan River, Shitouhe River, Pujiang River, xiejjiang River and the lower reaches of Nanhe River are relatively poor, and the correlation degree of the upper reaches of Xiaonan river is the lowest, which is 0.4071. The reason is that most of these
river sections are located in the areas where the population is relatively concentrated, which is greatly affected by human beings. The river hardening, livestock and poultry breeding, farmland planting and the wide distribution of industrial enterprises in the basin lead to the deterioration of river water quality, the decline of water ecological function and the poor water ecological environment.

4. Conclusions
In this paper, the grey relational model combined with the accessibility of data was used to select 11 indicators from three aspects of river water quality, aquatic ecology and water habitat to conduct a comprehensive evaluation on the water ecological environment of Nanhe small watershed. The evaluation results achieved the expected results, and the comprehensive evaluation of regional water ecological environment was basically feasible. According to the evaluation of grey correlation analysis, Wenjing River, Baimo River and Chujiang River have good ecological environment and sound ecological function. The control standard of these rivers should be improved to further ensure the health of water ecological environment. The water ecological environment of Xiaonan River, Shitouhe River, Pujiang River, xiejiang River and Nanhe River is poor, and the priority control level of these rivers is higher. The pollution control measures should be considered in combination with the ecological environment pressure of each river section. In the next step of research, we need to further study the selection and selection of indicators; for each index weighted modeling, the evaluation results are more convincing.

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