Computer Intelligent Evaluation Model of Jining Water Quality by Fuzzy Mathematics and Intelligent Computing

Xiao Huang*, Linlong Jiang and Caixing Jin

College of Geodesy and Geomatics, Shandong University of Science and Technology, Qingdao, China

*Corresponding author: xiaohuang@sdust.edu.cn

Abstract. This study uses fuzzy mathematics comprehensive evaluation method to evaluate the water environment quality of Jining City and summarize the spatial distribution of water pollutants. The results of the research show: (1) The pollution of surface waters in Jining City is relatively serious. The water quality of rivers is mostly Grade V. The pollution of lakes is relatively low. The overall pollution of reservoirs is relatively light. (2) The concentration distribution area of each pollutant is roughly in a "V" shape. The most polluted areas mainly occur in the Beijing-Hangzhou Canal, Old Canal and other places. The water environment quality in the eastern mountainous and hilly area is better.

Keywords: Water environment; Quality evaluation; Spatial distribution.

1. Introduction

Water is an irreplaceable natural resource that supports the development of the earth. Since the 21st century, due to the continuous growth of the population, the amount of available water resources has been rapidly reduced, and pollution has become increasingly serious. The water environment problem has gradually become a dangerous factor restricting social development and affecting people's health. The research on water environment quality assessment and its safeguard measures has become a hot spot of global concern [1, 2].

Jining City is located in the southwest of Shandong Province, with a total area of 110,000 km². Jining City has a well-developed water system, with the largest freshwater lake in Shandong Province—Nansi Lake. Nansi Lake has an area of 30,453 km², a volume of 1.606 billion m³, and 53 rivers that enter the lake. It is a multifunctional comprehensive lake and an important water source in Shandong Province. Nansi Lake is an important channel for the eastern route of the "South-to-North Water Diversion" project, and its water quality directly determines the success or failure of the eastern route. In summary, the strategic location of Nansi Lake is very important. The existing research on the water resources of Jining City mainly focuses on the development and utilization of groundwater resources, the assessment of water resources vulnerability, the division of surface water environmental function zones, and the evaluation of water resources carrying capacity [3-5]. A review of the relevant literature on water and soil resources in Jining city shows that the previous studies on water and soil resources in Jining City are mostly static and qualitative analysis. In the study of water quality evaluation of surface water resources in Jining city, single factor index method and comprehensive pollution index method are
mainly adopted. These methods ignore the statistical difference between concentration values and have a weak comparative effect. In addition, the change of water quality is continuous, while the expression of pollutant concentration in the water quality standard is not continuous. It is difficult to use a specific classification standard to artificially evaluate the degree of environmental pollution [6, 7]. Since the American cybernetic expert Zadeh LA put forward the concept of fuzzy sets in 1965, fuzzy mathematics has developed rapidly and has been widely used in production practice [8, 9]. The method of fuzzy mathematics overcomes the shortcoming of the single sub-index model that is difficult to accurately distinguish when the value is critical to the water quality classification standard. Therefore, this paper attempts to use fuzzy mathematics evaluation method to evaluate the surface water environmental quality of Jining City comprehensively and objectively.

2. Research data and methods
In this study, Jining city was selected as the study area, and the required data included: Water function zoning map of Jining City; Water environmental quality monitoring data of 43 monitoring stations, including major rivers, lakes and reservoirs, in Jining city from 2000 to 2010; Jining city and various counties and cities of the bureau of water resources, environmental protection bureau, hydrology bureau of field research collected data.

The administrative district boundaries and the distribution of water quality monitoring points in Jining City are shown in Figure 1.

![Figure 1. The point of distribution of water quality monitoring in Jining](image)

2.1. Establish evaluation factor subset and evaluation grade set
According to the analysis of monitoring data, dissolved oxygen (DO), five-day biochemical oxygen demand (BOD5), manganese index (CODMN), ammonia nitrogen (NH3-N) and volatile phenol are the pollutants that pollute the main rivers in Jining city. In this paper, these five types of pollutants are selected as the index layer for the evaluation of river water quality, representing a collection of water environmental quality factors:

\[
U = \{DO, BOD_5, COD_{MN}, NH_3-N, V - P\} = \{U_1, U_2, U_3, U_4, U_5\}
\] (1)

Use the national surface water quality standards to evaluate the water quality of lakes and reservoirs. Incorporate two indicators of T-P and T-N into the evaluation system. The evaluation factor set of reservoir water quality is:
According to the "Surface Water Environmental Quality Standard" (GB3838-2002), the water environmental quality of Jining City is divided into five categories. Specifically divided into: Class I (clean), Class II (clean), Class III (light pollution) Class IV (medium pollution), Class V (heavy pollution). \( V \) represents the set of water environmental quality classification standards: \( V = \{ \text{class I, class II, class III, class IV, class V} \} \).

2.2. Establish membership function

The degree of membership is a parameter that describes the degree of correlation between the content of pollutants and each pollution level. According to the water environment assessment standard, this assessment adopts class I (j=1), class II (j=2), class III (j=3), class IV (j=4), class V (j=5). The larger the pollutant index value, the higher the pollution level.

2.3. Establish fuzzy relation matrix

Let \( R \) be the fuzzy relationship between \( U \) and \( V \), and \( r \) represents the degree of subordination of the j-th grading of the i-th water environmental quality factor. Fuzzy relation matrix:

\[
R = \begin{bmatrix}
     r_{11} & r_{12} & r_{13} & r_{14} & r_{15} \\
     r_{21} & r_{22} & r_{23} & r_{24} & r_{25} \\
     r_{31} & r_{32} & r_{33} & r_{34} & r_{35}
\end{bmatrix}
\]  

(3)

2.4. Create a weight set

Weights of environmental factors are measures of their role in determining water quality grades. There are many weighting methods in fuzzy comprehensive evaluation, which can be divided into standard weighting method and principal factor prominent weighting method. Standard weighting often leads to wrong conclusions because only differences between evaluation criteria are considered. Different weight definitions make the evaluation results vary greatly [10-12]. This paper adopts the weighting method of exceeding standard multiples and normalizes the weights. This method can not only highlight the role of major pollutants, but also consider the difference in standard values of different pollutants.

2.5. Fuzzy comprehensive evaluation

Combine the fuzzy weight vector and the single-factor fuzzy evaluation matrix \( R \) to obtain the fuzzy comprehensive evaluation vector \( B \) of each evaluation factor.

\[
B = A * R = \{ b_1, b_2, b_3, b_4, b_5 \}
\]  

(4)

3. Research results and analysis

3.1. Water quality evaluation of main rivers in Jining City

In order to find out the main pollutants and pollution levels, using fuzzy mathematics comprehensive evaluation method, 29 monitoring points were selected for the water quality evaluation of 10 major rivers in Jining City.
3.2. Water quality evaluation of main lakes and reservoirs in Jining City

Conduct water quality evaluation on the monitoring data of 14 monitoring stations in Jining City.

Table 2. Examples of water quality evaluation results for lakes and reservoirs

| Names of lakes and reservoirs | Results of fuzzy operation | Evaluation results | Exceeding standard items and exceeding multiples | DO | BOD₅ | COD₇₅ | NH₃-N | Phenol |
|-------------------------------|-----------------------------|--------------------|-----------------------------------------------|----|------|-------|-------|--------|
| Nanyang Lake                 | (0.132 , 0.066 , 0.079 , 0.495 , 0.227) | IV                 | 0.4                                           | 0.78 | 67   |
|                              | (0.144 , 0.055 , 0.102 , 0.180 , 0.520) | V                  | 0.1                                           | 8   | 0.78 |
|                              | (0.012 , 0.105 , 0.104 , 0.295 , 0.484) | V                  | 0.4                                           | 0.78 | 67   |

3.3. Spatial distribution of pollutants in water bodies

The result shows: The concentration distribution of various pollutants roughly presents a pollution law with a "V"-shaped trend. The most polluted areas mainly occur in the Beijing-Hangzhou Canal, Old Canal and other places. Human activities in the areas where these rivers flow are frequent and intense, the regional economy is relatively developed, and the urban area accounts for a large proportion of land. In the eastern mountainous and hilly areas, due to relatively weak human activities, the local water environment quality is relatively good. The water environment quality in the eastern mountainous and hilly area is better. The surface water body of Jining City is more polluted overall. Among them, there are the most monitoring points with river water quality of Grade V. The water pollution of lakes is generally less than that of rivers. The closer to the center of the lake, the lower the water pollution. The overall water quality of the reservoir is better than that of the lake.
Figure 2. Spatial distribution map of water pollution

4. Conclusion and discussion
This study uses fuzzy mathematics comprehensive evaluation method to evaluate the water environment quality of Jining City. Use ArcGIS to perform spatial analysis and processing of various pollutants. This study shows the spatial distribution of surface water pollution in Jining City. The main conclusions are
as follows: (1) Surface water pollution in Jining City is more serious. River water quality is mostly Grade V. Lake water pollution is relatively light. The overall water quality of the reservoir is better than that of lakes and rivers. (2) The concentration distribution of each pollutant roughly presents a "V"-shaped trend. The most polluted areas mainly occur in the Beijing-Hangzhou Canal, Old Canal, and other places.

This paper only conducts research on the environmental quality of surface water in Jining City. The next step can be to analyze the impact of land use changes in Jining City on water environmental quality. This has certain guiding significance for the quantitative analysis of regional water and soil environmental effects. In addition, the prediction of the future water environment security status of Jining City is a problem that needs to be further studied.

References
[1] J. Liu, Analysis on water resources management and protection measures, Clean the world. 2020 35(12) 41-42.
[2] M.T. He, Comprehensive Benefit Analysis of Water Resources Utilization in Weihai City Based on Analytic Hierarchy Process, Sichuan Environment. 2020 39(06) 74-79.
[3] H.T. Zhang, Y.Q. Shi, Development and protection of groundwater resources in Jining City, Groundwater. 2017 39(05) 54-55.
[4] R.Y. Li, L.C. Kun, C.P. Lu, H.Y. Si, X.Y. Hu, Application and Comparison of Evaluation Methods of Water Resources Carrying Capacity in Jining City, Water resources protection. 2018 34(06) 65-70.
[5] X.L. Jia, Exploration and Analysis on the Development, Utilization and Protection Measures of Groundwater Resources in Jining City, Groundwater. 2016 38(03) 61-62.
[6] L.B. Yang, Y.Y. Gao, Principles and Applications of Fuzzy Mathematics, Guangzhou South China University of Technology Press. 2006.
[7] Y. Yin, G. Huang, K. Hipel, Fuzzy relation analysis for multicriteria water resources management, Journal of water resources planning and management. 1999 125(1) 41-47.
[8] W.X. Ma, Fundamentals of Fuzzy Mathematics, Digital Communication World. 2019 (04) 235.
[9] Y.W. Guo, Analysis on the Principle and Application of Fuzzy Mathematics, Western Quality Education. 2015 1(18) 24.
[10] X.B. Mei, F.G. Wang, J.F. Cao, Application and Discussion of Fuzzy Comprehensive Evaluation Method in Water Quality Evaluation, World geology. 2000 19(2) 172-177.
[11] F.L. Cheng, Y.Z. MA, H.L. Shen, Y.J. Gen, C.C. Feng, Application of Fuzzy Comprehensive Evaluation Method in Water Environment Evaluation, Heilongjiang Science and Technology Information. 2014 (12) 104.
[12] S. Karmakar, P. Mujumdar, Grey fuzzy optimization model for water quality management of a river system, Advances in Water Resources. 2006 29(7) 1088-1105.