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Original Research Paper

Fuzzy Evaluation and Analysis of Surface Water

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ABSTRACT

The comprehensive evaluation of the monitoring data of surface water in Handan City, based on the model of fuzzy comprehensive evaluation, was made in this paper. According to the monitoring data, selecting seven evaluation factors, namely, permanganate index, BOD, total nitrogen, total phosphorus, ammonia, fluoride and dissolved oxygen, weight matrix has been established for each factor, and the weight of each factor was obtained in the assessment of water quality. Then using the membership function in fuzzy mathematics, computed the data measured, and obtained the corresponding water level. The result of the evaluation shows that the water quality of Handan city is V level, severely polluted, and it becomes a security risk to the residents' drinking water. Besides, it can be used as the scientific basis for water quality control.

INTRODUCTION

It is difficult to determine the ambiguity problem accurately in the environmental assessment. For example, in the evaluation of surface water, water quality is often between the standards of two countries, and for evaluators it is difficult to judge the quality of water. Therefore, the method of fuzzy evaluation can be recommended to resolve such problems in the evaluation of water quality (Lili Jiang 2007).

This paper is based on the ambiguity problem of the assessment of water quality, and treats the water environment as a fuzzy subset. Using the membership describes the classification boundaries of the water quality, and obtained the results of comprehensive evaluation through the operations of fuzzy matrix. Water quality assessment takes into account not only the ambiguity of water level boundary, but also the contribution of various water quality parameters in the pollution, and given the different weights. Therefore, every factor is clear and quantitative when describes the degree of water pollution, reflecting the comprehensive water quality of monitoring sections, and ultimately determining the water quality level (Yang 2000).

THE STUDY AREA

Handan City is in the south of Heibei Province, the east of Taihang Mountain, at the junction of four provinces. It locates between longitude 113°28'~ 115° 48' and latitude 36°03'~ 37 °01'. It borders Liaocheng in Shandong Province on the east, Anyang in Henan Province on the south, Changzhi in Shanxi Province on the west and Xingtai on the north. The longest distance from north to south is 104 km, and east to west is 180 km. The total area is 12,062 square kilometers, of which the urban area is 434 square kilometers, and the city built-up area is 106 square kilometers. The total population is about 10 million, of which the urban population is 1.8 million. The territory terrain in west is higher than east, and is 48.7~1898.7 m above sea level. The main rivers within the city are Zhang river of Nanyun water system, Fuyang river of Ziya Water system and its tributaries Niumang river, Jian river, Zhu river, Qin river, Shuyuan river, Nanming river and Beiming river etc.

THE METHOD OF FUZZY COMPREHENSIVE EVALUATION

Evaluation criteria: Water Quality Standards (GB3838-2002) issued by the State is the evaluation criteria (Ministry of Environmental Projection of China 2002).

The establishment of fuzzy matrix: The fuzzy relation matrix R represents the membership of each pollution factor to environmental quality standards for each level, therefore, the membership can be seen as the function between the concentration of pollutants and environmental quality standards. Supposing that the environmental quality standard is divided into n levels, if the concentration of pollutant is lower than the first level, so its membership for the first level is 1, and for other levels is 0. Similarly, if the concentration of pollutant is higher than the n level, so its membership for the n level is 1, and for other levels is 0. After having the representative value of grading, the subjection degree can be calculated based on where the actual value of environmental factors is located between the two representatives. Therefore, the membership of each factor to each environmental quality level can be calculated like this:

1. For the evaluation factors of smaller but more superior type, such as COD, its membership function is given in the following formula (Hao & Jiang 2010). The first level of the evaluation membership function:

$$r_{i1} = \begin{cases} 0 & x \geq v_{i2} \\ \dfrac{x - v_{i2}}{v_{i1} - v_{i2}} & v_{i1} < x < v_{i2} \\ 1 & x \leq v_{i1} \end{cases} \quad ...(1)$$

Evaluation membership functions of the *j*-level:

$$r_{ij} = \begin{cases} 0 & x \leq v_{i(j-1)} \\ \dfrac{x - v_{i(j-1)}}{x_{ij} - v_{i(j-1)}} & v_{i(j-1)} < x \leq v_{ij} \\ \dfrac{x - v_{i(j+1)}}{v_{ij} - v_{i(j+1)}} & v_{ij} < x < v_{i(j+1)} \end{cases} \quad ...(2)$$

Evaluation membership functions of the *n*-level.

$$r_{in} = \begin{cases} 0 & x < v_{i(n-1)} \\ \dfrac{x - v_{i(n-1)}}{v_{in} - v_{i(n-1)}} & v_{i(n-1)} < x < v_{in} \\ 1 & x \geq v_{in} \end{cases} \quad ...(3)$$

2. For the evaluation factors of larger and more superior type, such as DO, its membership function is given in the following formula: The evaluation membership of the function first level:

$$r_{i1} = \begin{cases} 0 & x \geq v_{i2} \\ \dfrac{x - v_{i2}}{v_{i1} - v_{i2}} & v_{i2} < x < v_{i1} \\ 1 & x \leq v_{i1} \end{cases} \quad ...(4)$$

Evaluation membership functions of the *j*-level:

$$r_{ij} = \begin{cases} 0 & x \geq v_{i(j-1)} \quad x \leq v_{i(j+1)} \\ \dfrac{x - v_{i(j-1)}}{v_{ij} - v_{i(j-1)}} & v_{ij} \leq x < v_{i(j-1)} \\ 1 & v_{i(j+1)} < x \leq v_{ij} \end{cases} \quad ...(5)$$

Evaluation membership functions of the *n*-level:

$$r_{in} = \begin{cases} 0 & x \leq v_{in} \\ \dfrac{x - v_{i(n-1)}}{v_{in} - v_{i(n-1)}} & v_{in} < x < v_{i(n-1)} \\ 1 & x \geq v_{i(n-1)} \end{cases} \quad ...(6)$$

For each evaluation factor, apply the formula above to get the corresponding value of membership according to their category. Based on the calculation above, it is available to a single factor fuzzy evaluation set for each factor correspondingly. If there are *n* items of water quality parameters and *m* classes quality standards, we can write the following *n* × *m* fuzzy matrix.

$$R = \begin{bmatrix} r_{11} & \cdots & r_{1m} \\ \vdots & \ddots & \vdots \\ r_{n1} & \cdots & r_{nm} \end{bmatrix}$$

Determination of the weight set: Due to the different effects of various monitoring indicators to water quality, it is neccesary to give the different weights in accordance with its role in water quality (Lu 2011). The formula is as follows:

$$W_i = \frac{c_i}{s_i} \quad ...(7)$$

In the formula, *Ci* is the measured concentration of the individual factors and *Si* is the specified level concentration of the individual evaluation criteria.

Take w_i for normalized, and obtain the weight values of factors.

$$a_i = \frac{w_i}{\sum w_i} \quad ...(8)$$

Using the a_i derived from formula above to set up the factor weight set A.

Fuzzy comprehensive evaluation: Using the basic model of fuzzy comprehensive evaluation: B = A × R, according to the location of the maximum vector in the results, the water quality can be judged directly (Xingui He 1998).

STATUS EVALUATION OF SURFACE WATER

Position of water sampling section: Fuyang River, Zhang River and Wei River in Handan city were monitored, and in each river three monitoring sections were selected, summing up to total nine sections.

The selection of evaluation factors: Evaluation factors for each section: Permanganate index, BOD, total nitrogen, ammonia, fluoride, total phosphorus, dissolved oxygen. The average values are shown in Table 1.

Water quality evaluation criteria: The status evaluation criteria of surface water was selected from National Standard GB3838-2002. The specific standard value is given in Table 2.

Calculation of membership: Taking the monitoring data of the pollution index of each section listed in Table 1 into the formula (1) - (6), membership can be calculated of each section and pollution factors. The membership results are shown in Table 3.

Calculation of weight coefficients: Fuzzy computing required to determine the value of pollutant concentration standard *Si*.

According to GB3838-2002, to get its mean value:

$$S_i = (S_I + S_{II} + S_{III} + S_{IV} + S_V)/5 \quad ...(9)$$

The results of each value of pollutant *Si* are shown in Table 4.

The weight coefficient shows the important degree of one index in the index system; it indicates when the other index item was under the condition of invariable, the change of the index caused the influence of the results. In the fuzzy evaluation of the water quality, the contribution to water pollution of every evaluation factors is different, so need to give the different weights respectively according to the difference of role to the water quality. According to the data of the Table 1 and Table 2, we can calculate the value of the weight of the pollution factor, and the result is shown in Table 5.

Calculation of fuzzy index: The principles of weighted average were used to determine fuzzy composite index B*. In order to deal with it quantitatively, using "1, 2, 3, ..., m" to stand for each class, and call it as the level of rank. Then using the corresponding component of B, the sum of each level of rank was calculated to get the relative position of things evaluated (Hongjie Wang & Bin You 2005).

It can be expressed as:

$$B^* = \frac{\sum_{j=1}^{m} b_j^k \times j}{\sum_{j=1}^{m} b_j^k} \quad ...(10)$$

In the formula:

B^* - It represents the relative position of each grade of the water body evaluated.
b_j- Membership grade belonging to the *j* level.
k- Undetermined coefficient (*k* =1 or *k* =2)

Table 1: The monitoring data of surface water in Handan city (mg/L).

Section	CODmn	BOD_5	TN	NH_3-N	Fluoride	TP	DO
Jiu haoquan	1.37	1.62	4.52	0.012	0.41	0.304	8.22
Cement bridge	4.56	2.72	7.24	0.67	0.58	0.078	8.39
Quzhou	12.66	5.37	8.17	1.64	1.49	0.468	6.4
Liu jiazhuang	2.03	1.88	4.57	0.145	0.35	0.028	8.62
Lian quan	3.36	2.85	5.91	0.335	0.73	0.079	7.84
Xi da	2.55	2.22	5.86	0.208	0.58	0.073	7.92
Long wangmiao	15.1	10.4	0.355	5.69	1.26	0.355	9.00
Xu wancang	14.13	8.66	10.26	4.77	1.01	0.323	6.86
Luo touqiao	14.1	9.06	10.07	4.6	1.00	0.331	6.98

Table 2: Standard limit of surface water quality (mg/L).

Project	I	II	III	IV	V
CODmn	2	4	6	10	15
BOD_5	3	3	4	6	10
TN	0.2	0.5	1.0	1.5	2.0
NH_3-N	0.15	0.5	1.0	1.5	2.0
Fluoride	1.0	1.0	1.0	1.5	1.5
TP	0.02 (lake-reservoir 0.001)	0.1 (lake-reservoir 0.025)	0.2 (lake-reservoir 0.05)	0.3 (lake-reservoir 0.1)	0.4 (lake-reservoir 0.2)
DO	7.5	6	5	3	2

Table 3: The results of membership of pollution factors to each classification standard.

	Grade	CODmn	BOD_5	TN	NH_3-N	Fluoride	TP	DO
Jiu haoquan	I	1	1	0	1	1	0	1
	II	0	0	0	0	0	0	0
	III	0	0	0	0	0	0	0
	IV	0	0	0	0	0	0.96	0
	V	0	0	1	0	0	0.04	0
Cement bridge	I	0	1	0	0	1	0.275	1
	II	0.72	0	0	0.66	0	0.725	0
	III	0.28	0	0	0.34	0	0	0
	IV	0	0	0	0	0	0	0
	V	0	0	1	0	0	0	0
Quzhou	I	0	0	0	0	0	0	0.27
	II	0	0	0	0	0	0	0.73
	III	0	0.315	0	0	0.02	0	0
	IV	0.468	0.685	0	0.72	0.98	0	0
	V	0.532	0	1	0.28	0	1	0
Liu jiazhuang	I	0.985	1	0	0	0	0.9	1
	II	0.015	0	0	0	0	0.1	0
	III	0	0	0	0	0	0	0
	IV	0	0	0	0.72	0	0	0
	V	0	0	1	0.28	1	0	0
Lianquan	I	0.32	1	0	0.47	1	0.26	1
	II	0.68	0	0	0.53	0	0.74	0
	III	0	0	0	0	0	0	0
	IV	0	0	0	0	0	0	0
	V	0	0	1	0	0	0	0
Xida	I	0.725	1	0	0.834	1	0.34	1
	II	0.275	0	0	0.166	0	0.66	0
	III	0	0	0	0	0	0	0
	IV	0	0	0	0	0	0	0
	V	0	0	1	0	0	0	0
Long wangmiao	I	0	0	0.48	0	0	0	1
	II	0	0	0.52	0	0	0	0
	III	0	0	0	0	0.48	0	0
	IV	0	0	0	0	0.52	0.45	0
	V	1	1	0	1	0	0.55	0
Xu wancang	I	0	0	0	0	0	0	0.57
	II	0	0	0	0	0	0	0.43
	III	0	0	0	0	0.98	0	0
	IV	0.174	0.335	0	0	0.02	0.77	0
	V	0.826	0.665	1	1	0	0.33	0
Luo touqiao	I	0	0	0	0	0.33	0	0.65
	II	0	0	0	0	0.33	0	0.35
	III	0	0	0	0	0.33	0	0
	IV	0.18	0.235	0	0	0	0.69	0
	V	0.82	0.765	1	1	0	0.31	0

According to the data of Tables 3 and 5, calculated the fuzzy index of each cross-section, and the results are given in Table 6 (Qiang Fu 2011, Li Liu 2010).

Evaluation results: Through the analysis of membership grade and weight factor of each pollution factor of the grading standards, all sections are V level water body.

CONCLUSION

Water pollution degree, water quality classification boundaries, etc. are some vague concepts and phenomena. By using fuzzy comprehensive index method for water quality assessment, in contrast with other methods, it has the following advantages: (a) At the same level of water, the water quality is not the same, just from the monitoring data it is difficult to distinguish the difference, and the fuzzy comprehensive index method can clearly determine the water quality index level. (b) Fuzzy comprehensive index method use fuzzy membership functions to describe the water quality classification boundaries, note the ambiguity of the actual boundaries, so that evaluation results close to the objective.

Table 4: The results of S_i.

Evaluation factor	CODmn	BOD_5	TN	NH_3-N	Fluoride	TP	DO
Si	7.4	5.2	1.04	1.03	1.2	0.204	4.7

Table 5: The weight coefficient calculation of pollution factor of surface waters in Handan.

Section		CODmn	BOD_5	TN	NH_3-N	Fluoride	TP	DO
Jiu haoquan	*Ci*	1.37	1.62	4.52	0.012	0.41	0.304	8.22
	Ci/Si	0.185	0.312	4.346	0.012	0.342	1.49	1.749
	ai	0.022	0.037	0.515	0.001	0.041	0.177	0.207
Cement bridge	*Ci*	4.56	2.72	7.24	0.67	0.58	0.078	8.39
	Ci/Si	0.626	0.523	6.962	0.65	0.483	0.382	1.785
	ai	0.055	0.046	0.610	0.057	0.042	0.033	0.156
Quzhou	*Ci*	12.66	5.37	8.17	1.64	1.49	0.468	6.4
	Ci/Si	1.71	1.03	7.856	1.592	1.242	2.294	1.362
	ai	0.100	0.060	0.460	0.093	0.073	0.134	0.080
Liu jiazhuang	*Ci*	2.03	1.88	4.57	0.145	0.35	0.028	8.62
	Ci/Si	0.274	0.362	4.394	0.141	0.292	0.137	1.834
	ai	0.037	0.049	0.591	0.019	0.039	0.018	0.247
Lian quan	*Ci*	3.36	2.85	5.91	0.335	0.73	0.079	7.84
	Ci/Si	0.454	0.548	5.683	0.325	0.608	0.387	1.668
	ai	0.047	0.057	0.586	0.034	0.063	0.040	0.172
Xida	*Ci*	2.55	2.22	5.86	0.208	0.58	0.073	7.92
	Ci/Si	0.345	0.427	5.635	0.202	0.483	0.358	1.685
	ai	0.038	0.047	0.617	0.022	0.053	0.039	0.184
Long wangmiao	*Ci*	15.1	10.4	0.355	5.69	1.26	0.355	9.00
	Ci/Si	2.04	2	0.341	5.524	1.05	1.740	1.915
	ai	0.140	0.137	0.023	0.378	0.072	0.119	0.131
Xu wangchang	*Ci*	14.13	8.66	10.26	4.77	1.01	0.323	6.86
	Ci/Si	1.909	1.665	9.865	4.631	0.842	1.583	1.460
	ai	0.087	0.076	0.449	0.211	0.038	0.072	0.066
Luo touqiao	*Ci*	14.1	9.06	10.07	4.6	1.00	0.331	6.98
	Ci/Si	1.905	1.742	9.683	4.566	0.833	1.623	1.485
	ai	0.087	0.080	0.443	0.209	0.038	0.074	0.068

Table 6: The results of fuzzy index of surface water in Handan.

Section	I	II	III	IV	V	Evaluation results
Jiu haoquan	0.308	0	0	0.170	0.522	V level water
Cement bridge	0.089	0.101	0.035	0	0.610	V level water
Quzhou	0.022	0.058	0.020	0.226	0.673	V level water
Liu jiazhuang	0.407	0.002	0	0	0.591	V level water
Lianquan	0.333	0.080	0	0	0.586	V level water
Xida	0.343	0.040	0	0	0.617	V level water
Long wangmiao	0.142	0.012	0.035	0.091	0.720	V level water
Xu wangchang	0.050	0.037	0.037	0.097	0.799	V level water
Luo touqiao	0.057	0.036	0.013	0.086	0.617	V level water

(c) Considering the role differences of parameters in the overall pollution, it gives different weights. Using fuzzy comprehensive index method, it makes comprehensive evaluation of water quality; in theory, it is more rigorous. Fuzzy mathematics as a method, is not only used to evaluate the water quality, but also the atmosphere, biology, physics and other environmental quality assessment, and make the evaluation results closer to the objective reality.

The evaluation showed that the surface water in Handan city is heavily polluted. The main pollution sources include as follows: First, the basin pollutants discharged into the river directly. Second, through the heavy rain, which form surface runoff, will take the pollutants into the surface waters. Third, the river precipitation (including rain, snow, fog, etc.) contains pollutants. Fourth, the river dust (referring to dry down) caused water pollution. Fifth, harmful gases in the air are dissolved in lake water forming water pollution. Sixth, spilled solid pollutants to the lake formed water pollution. Although the Handan Municipal Government has made many efforts in the protection of water quality of surface water, came on a series of measures and closed many factories and restaurants in the basin, but the road of the water environment protection is a long way to go. With the economic development of Handan city, the source of pollutants will become increasingly widespread.

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REFERENCES

Hao, Shengjie and Jiang, Changsheng 2010. Application of fuzzy mathematical method in environmental quality evaluation of Qingyang section in Jiang'an River. Journal of Southwest China Normal University, 35(2): 137-139.

Hongjie Wang and Bin You 2005. Application of fuzzy mathematics evaluation to water quality. Hydrology, 25(12): 23-25.

Li Liu 2010. Using fuzzy theory and information entropy for water quality assessment in three Gorges region. Expert Systems with Applications 37(3): 2517-2521.

Lili Jiang 2007. Application of fuzzy mathematics evaluation to water quality of Qinglong River. Journal of Dalian Institute of Light Industry, 26 (1): 56-57.

Lu, Shuyu 2011. Environmental Impact Assessment. Beijing, Higher Education Press, 2011.

Ministry of Environmental Projection of China 2002. GB3838-2002 Quality standards of Surface water. China Environmental Science Press, 2002.

Qiang Fu 2011. Water quality evaluation by the fuzzy comprehensive evaluation based on EW method. Fuzzy Systems and Knowledge Discovery, 26(9): 476-479.

Xingui He 1998. Fuzzy Theories and Fuzzy Techniques in Knowledge Processing. Beijing, National Defense Industry Press, 1998.

Yang, Lin 2000. Application of fuzzy mathematics evaluation to water quality of the wet watershed. China Environmental Monitoring, 16(6): 49-52.