Nature Environment and Pollution Technology
An International Quarterly Scientific Journal

ISSN: 0972-6268	Vol. 13	No. 3	pp. 517-521	2014

Original Research Paper

The Fuzzy Comprehensive Evaluation of Water Quality Based on Weighted Modified in Beijing Garden Show Park

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Nat. Env. & Poll. Tech.
Website: www.neptjournal.com
Received: 22-4-2014
Accepted: 18-6-2014

Key Words:
Garden show park
Yongding river
Water quality
Fuzzy comprehensive evaluation method

ABSTRACT

In recent years, due to the speeding up of urbanization, the water quality of Yongding river in Beijing is deteriorating. The Garden Show Park was built beside the Yongding river. In this paper, we have made scientific and reasonable evaluation on the water environment of the park, tracking its ecological effect in real time, to provide certain reference for the corresponding improvement measures. Firstly, we collected some water samples in the river, conducted an experiment later, and then we used the improved special operation to calculate the fuzzy result, which is based on the principle of fuzzy comprehensive evaluation. At the same time, we increase the evaluation section, and balance the evaluation results of every section, it is concluded that the water quality level is: the third level (light pollution), and it provides referential basis for the ecological restoration of the river.

INTRODUCTION

Beijing Garden Show Park is the site of the ninth China International Garden Expo, located beside the Yongding river, in Fengtai district in southwest of Beijing. The water quality of the area has a great influence on the water environment of downstream. In order to make the water quality reach the standard of third kind of water as much as possible, Beijing Institute of Water has designed the method of using artificial wetland to purify water. But, the water area is currently an artificial ornamental river, its surrounding human activity is frequent, and the self-purification ability is limited, so making deep evaluation on the quality of the water area is of great significance to proceed the ecological restoration on Yongding river and turn Beijing to the International livable city.

The river water environment evaluation is based on the data of the experiment. It evaluates the factors of water quality qualitatively or quantitatively according to certain model to confirm the category of water quality and reflect the status of water quality accurately (Liu et al. 2010). However, there is a lot of fuzziness in water environmental quality when we determine it as "good" or "bad". So using fuzzy comprehensive evaluation method to evaluate the water environment is more appropriate. At present, many experts at home and abroad have studied the method of fuzzy comprehensive evaluation of water environment. They have put forward a lot of ideas which are feasible and provide an important basis for quantitative analysis of water environment (You et al. 2012, Guo et al. 2012, Chi & Li 2013, Fu et al. 2011, Han et al. 2013).

THE FUZZY COMPREHENSIVE EVALUATION MODEL

Fuzzy comprehensive evaluation is a model that the fuzzy mathematics theory is introduced into, and it is used to solve the problems of fuzzy quantitatively. Fuzzy mathematical theory quantifies the uncertainty in the system by membership degree, confirms the relation between factors and standards, and then uses the weight relationship of evaluation factors, and finally calculated the evaluation results. The specific steps of the method are: (1) establish the set of water quality evaluation factors and level set; (2) establish single factor evaluation matrixes; (3) determine the weights of each factor; (4) establish the water quality evaluation model, and calculate the evaluation results (Song et al. 2013).

The establishment of the evaluation factors and evaluation set: The selected evaluation factors are the major pollution elements that have representativeness to reflect the environment quality condition, such as COD (Chemical Oxygen Demand), etc.

The set of evaluation factors is made up of the elements that affect the evaluation objects, and generally, it is expressed as follows:

$$\mathrm{U} = \{u_1, u_2, \cdots, u_n\} u_i (i = 1,2,\cdots,\mathrm{n}) \quad ...(1)$$

In the type above, u_i is the i^{th} factor in the set. We should maintain the principle that the selected evaluation factors can reflect the general characteristics of water.

The determination of membership function: The boundaries of environmental quality are fuzzy problems, so we adopt the method of fuzzy mathematics, using the membership degree to describe that which level dose the water environment quality belong to. First, we establish each classification standard for water quality, and then determine mem-bership function that each evaluation factor matches. The membership functions of each factor are determined as follows:

(1) When the water qualify is the first level, name-ly j = 1, membership function is shown as type (2).

$$Y_{ij} \begin{cases} = 1, & x_i \le S_{ij} \\ = A_{ij}(x_i - S_{i(j+1)}), & S_{ij} < x_i < S_{i(j+1)} \\ = 0, & x_i \ge S_{i(j+1)} \end{cases} \quad ...(2)$$

In the type above, x_i is the measured values of the i^{th} factor, mg/L; S_{ij} is the j^{th} water's standard values of the i^{th} factor, mg/L; $S_{i(j+1)}$ is the $(j+1)^{th}$ water's standard values of the i^{th} factor, mg/L; A_{ij} is a coefficient which equals to the mid-value of two adjacent standards. The mid-value for the two adjacent standards membership degree is 0.5, and because the mid-value can be replaced by the mean value of two adjacent standards, we could get by putting mean value and membership degree into the type:

$$y_{\mathrm{ij}} = A_{\mathrm{ij}}(x_j - S_{I(J+1)})$$

$$A_{\mathrm{ij}} = \frac{1}{S_{\mathrm{ij}} - S_{i(j+1)}} \quad ...(3)$$

(2) When the water qualify is the second to $(m\text{-}1)^{th}$ level, namely j = 2, 3, ..., $(m\text{-}1)$, membership function is shown as type (4).

$$y_{\mathrm{ij}} = \begin{cases} 1, & x_j \le S_{i(j-1)}; \\ A_{\mathrm{ij}}(\mathrm{x}_i - S_{i(j-1)}), & S_{i(j-1)} < x_i < S_{\mathrm{ij}}; \\ A*_{ij}(\mathrm{x}_i - S_{i(j+1)}), & S_{\mathrm{ij}} \le x_i \le S_{i(j+1)}; \end{cases} \quad ...(4)$$

In the type above, $S_{i(j+1)}$ is the $(j\text{-}1)^{th}$ water's standard values of the i^{th} factor, mg/L; A_{ij}, $A*_{ij}$ are two coefficients, they can be obtained by the types (5) and (6).

$$A_{\mathrm{ij}} = \frac{1}{S_{\mathrm{ij}} - S_{i(j-1)}} \quad ...(5)$$

$$A*_{ij} = \frac{1}{S_{\mathrm{ij}} - S_{i(j+1)}} \quad ...(6)$$

The other symbols are the same as above.

(3) When the water qualify is the last level, namely $J = m$, membership function is shown as type (7).

$$y_{\mathrm{ij}} = \begin{cases} 1, & x_j \ge S_{i(j-1)}; \\ A_{\mathrm{ij}}(\mathrm{x}_i - S_{i(j-1)}), & S_{i(j-1)} < x_i < S_{\mathrm{ij}}; \\ 0, & x_i < S_{i(j-1)}; \end{cases} \quad ...(7)$$

In the type, A_{ij} is the same as type (5), and the other symbols are the same as above.

To establish about the weight of each factor matrix: For a single point of each evaluation factor, because contributions of various factors to the water quality pollution are different, we can compare and give different weights by the various factors in the role of environmental change. There are some methods of weight calculation in common:

$$w_i = \frac{x_i}{S_i} \quad ...(8)$$

In the type, x_i is the i^{th} factor in measuring point measured values, mg/L; S_i is the average value of the i^{th} factor's standard value, mg/L.

In this way, through the type (8), we can calculate the weight of each factor of the single point, it can be shown as the matrix W = $\{w_1, w_2 ... w_n\}$.

The improvement about fuzzy comprehensive method of compound operation: Generally, in the fuzzy comprehensive evaluation method, there are several kinds of compound operations about each factor's membership degree matrix and its weight matrix:

1. Two corresponding matrix values multiply each other, then add those results of each row;
2. Take the smaller of the two corresponding matrix values, then get the biggest of those selected values of each row;
3. Two corresponding matrix values multiply each other, then get the biggest of those results of each row;
4. Take the bigger of the two corresponding matrix values, then get the smallest of those selected values of each row;

However, in the several ways the above have problems such as lose the general information, and highlight the main factors. So we introduced a new method of compound operation - the weighted average method (Kou 2013). In this method, the weight value multiply to corresponding membership degree value of each factor, and then calculating

Table 1: The test results of water quality indicators.

Section	Section 1				Section 2			
Water Samples	1	2	3	4	1	2	3	4
pH	8.2	8.25	8.23	8.19	8.11	8.21	8.16	8.17
Hardness(mg/L)	201.1	204.5	195.7	207.9	234	219.9	226.0	207.8
Turbidity(NTU)	18.7	21.2	26.6	15.5	19.2	20.4	25.6	20.5
Conductivity(us/cm)	812	815	817	807	831	823	811	809
CODCr (mg/L)	22.4	40.3	34.7	41.4	17.9	36.9	28	15.6
CODMn (mg/L)	5.7	5.54	5.6	5.44	5.16	5.22	5.36	5.3
Ammonia nitrogen(mg/L)	0.54	0.66	0.63	0.67	0.49	0.56	0.52	0.56
Section	Section 3				Section 4			
Water Samples	1	2	3	4	1	2	3	4
pH	8.62	8.55	8.56	8.5	8.57	8.44	8.45	8.52
Hardness(mg/L)	231.9	304.91	203.72	207.85	201.7	219.85	177.5	227.9
Turbidity(NTU)	20.7	25.9	21.3	20.1	23.7	23.3	21	25.8
Conductivity(us/cm)	832	815	830	829	836	820	831	846
CODCr (mg/L)	42.56	50.4	39.2	56	31.36	24.64	35.84	36.96
CODMn (mg/L)	6.94	6.72	6.98	7.04	5.62	5.72	5.64	5.66
Ammonia nitrogen(mg/L)	0.777	0.769	0.799	0.788	0.513	0.478	0.545	0.532
Section	Section 5				Section 6			
Water Samples	1	2	3	4	1	2	3	4
pH	8.42	8.45	8.45	8.45	8.42	8.41	8.41	8.42
Hardness(mg/L)	203.72	252.13	238.01	201.7	217.84	221.87	226.02	205.73
Turbidity(NTU)	19.3	20.4	27.8	20.3	25.1	22.5	24.4	23.4
Conductivity(us/cm)	823	835	830	828	819	823	821	819
CODCr (mg/L)	33.6	34.72	41.44	31.36	36.96	29.2	29.12	25.76
CODMn (mg/L)	5.8	5.84	5.75	5.74	6.02	6.13	6.1	6.17
Ammonia nitrogen(mg/L)	0.432	0.443	0.448	0.437	0.445	0.437	0.46	0.464

the square root of that result. We should also balance the calculation results by the type (9).

The final evaluation index is expressed as B,

$$B = W \odot R =$$

$$[w_1 \quad w_2 \quad \cdots \quad w_n] \odot \begin{bmatrix} y_{11} & y_{12} & \cdots & y_{1n} \\ \vdots & \vdots & \vdots & \vdots \\ y_{i1} & y_{i2} & \cdots & y_{in} \\ \vdots & \vdots & \vdots & \vdots \\ y_{n1} & y_{n2} & \cdots & y_{nn} \end{bmatrix} =$$

$$\begin{bmatrix} \sqrt{w_1 y_{11}} & \sqrt{w_1 y_{12}} & \cdots & \sqrt{w_1 y_{1n}} \\ \vdots & \vdots & \vdots & \vdots \\ \sqrt{w_i y_{i1}} & \sqrt{w_i y_{i2}} & \cdots & \sqrt{w_i y_{in}} \\ \vdots & \vdots & \vdots & \vdots \\ \sqrt{w_n y_{n1}} & \sqrt{w_n y_{12}} & \cdots & \sqrt{w_n y_{nn}} \end{bmatrix} \quad \ldots(9)$$

then let

$$B = \sqrt{F_{1max}^2 + F_1^2}\sqrt{F_{2max}^2 + F_2^2} \ldots \sqrt{F_{nmax}^2 + F_n^2}$$

in this type,

$$F_{jmax} = \max(\sqrt{w_1 y_{11}}, \sqrt{w_2 y_{2j}}, \ldots, \sqrt{w_n y_{nj}})$$

j=(1,2,3……n)

F_j equals to the average of

$\sqrt{w_1 y_{11}}, \sqrt{w_2 y_{2j}}, \ldots, \sqrt{w_n y_{nj}}$ j=(1,2,3……n)

Then comparing B and the standard value of the surface water quality classification, we can obtain the final evaluation index.

THE EXAMPLE ANALYSIS

Data information and evaluation standard: We have evaluated the water quality of Beijing Garden show park by the model above. In this experiment, we divided the investigated river into six sections. In each section, we took four water samples whose each two have the same distance. The main parameters studied were pH, hardness, turbidity, conductivity, COD_{Cr} (Chemical Oxygen Demand of Cr), potassium permanganate index, and ammonia nitrogen. We have got measured index of water quality data as given in Table 1. The evaluation criteria is based on surface water environmental quality standards (GB 3838-2002), each

Table 2: The cross section of average water quality indicators.

	Section 1	Section 2	Section 3	Section 4	Section 5	Section 6
pH	8.2	8.2	8.6	8.5	8.4	8.4
Hardness (mg/L)	202	222	237	207	224	218
Turbidity (NTU)	21	21	22	23	22	24
Conductivity (μs/cm)	812.8	818.5	826.5	833.3	829.0	820.5
CODCr (mg/L)	34.7	24.6	47.0	32.2	35.3	30.3
CODMn (mg/L)	5.57	5.26	6.92	5.66	5.78	6.11
Ammonia nitrogen (mg/L)	0.63	0.54	0.78	0.52	0.44	0.45

Table 3: The surface water environment quality standards.

	I	II	III	IV	V	Average
pH	7	7.5	8.5	9.5	9.5	8.4
Hardness (mg/L)	150	300	450	550	550	400
Turbidity (NTU)	3	3	3	10	10	5.8
Conductivity (μs/cm)	100	400	800	1000	1000	660
CODCr (mg/L)	15	15	20	30	40	24
CODMn (mg/L)	2	4	6	10	15	7.4
Ammonia nitrogen(mg/L)	0.015	0.5	1	1.5	2	1.003

Table 4: The weight of each water quality index value.

	The weight assembly of evaluation factors					
	Section 1	Section 2	Section 3	Section 4	Section 5	Section 6
pH	0.98	0.97	1.02	1.01	1.01	1.00
Hardness (mg/L)	0.51	0.55	0.59	0.52	0.56	0.54
Turbidity (NTU)	3.53	3.69	3.79	4.04	3.78	4.11
Conductivity (μs/cm)	1.23	1.24	1.25	1.26	1.26	1.24
CODCr (mg/L)	1.45	1.03	1.96	1.34	1.47	1.26
CODMn (mg/L)	0.75	0.71	0.94	0.76	0.78	0.83
Ammonia nitrogen (mg/L)	0.61	0.52	0.76	0.50	0.43	0.44

Table 5: The section evaluation index.

	Section 1	Section 2	Section 3	Section 4	Section 5	Section 6
The evaluation index	0.86	0.78	1.08	1.03	0.71	1.06

Table 6: Each section of surface water quality classification.

Classification	Level 1 clean	Level 2 cleaner	Levels 3 light pollution	Level 4 secondary pollution	Level 5 heavy pollution
The evaluation index B	< 0.7	0.71~0.9	0.91~1.50	1.51~3.00	>3.00

factor's values are given in Table 3.

According to the data in Table 1, take the average value of measured data of water quality index as the average value of each index of the section, and these are given in Table 2.

The evaluation results: According to the type (9), calculating the weight of each factor in the section, as shown in Table 4, and its membership degree for level I to V of water quality. Then use the improved compound operation to calculate the evaluation index, as given in Table 5. Finally, calculate the average value of the evaluation index of each section:

$$\bar{B} = \frac{\sum_{i=1}^{6} B_i}{6} = 0.92$$

According to the water quality classification of the surface water (Hou 2012), the quality of this water area is the third level which belongs to light pollution.

CONCLUSIONS

1. The improved fuzzy comprehensive evaluation method eliminates the disadvantage of the traditional method called "lose the general information, highlight the main factors". It more objectively reflects the influence of multiple evaluation factors in water pollution. We can systematically solve the uncertain problems using this method.
2. According to results of the experiment of water indexes, although each sampling section is close to another, and sampling density is larger, the water evaluation results of each section vary obviously. This reflects that the stability of the man-made river environment is low, self-purification ability is poor, and it is more vulnerable by human activities. We think it has close relationship with the source of reclaimed water in the man-made river.
3. On the whole, the water quality of Garden Show Park in Beijing is good, its governance has received obvious effects. But we should still select evaluation factors carefully according to the actual situation of local basin environment year by year, so as to ensure the objectivity and accuracy of the evaluation results.

ACKNOWLEDGMENTS

This work was supported by the funds for undergraduate innovative experiment plan of North China Electric Power University (national level), and the Open Research Fund Program of State Key Laboratory of Hydroscience and Engineering, No. sklhse-2013-A-03. The work was also supported by "the Fundamental Research Funds for the Central Universities" (No. 2014ZD12), and the Open Research Fund Program of State Key Laboratory of Hydrlology-Water Resources and Hydraulic Engineering, Hohai University, No. 2013490811, and by 12th Five-Year National Key Technology R&D Program (No. 2012BAB05B05).

REFERENCES

Chi, Y. and Li, S.F. 2013. Analysis on the quality of urban lake water environment based on the improved fuzzy comprehensive evaluation method. Journal of Huazhong Normal University, 47(1): 124-128.

Fu, J.X., Chen, Z., Ma, X.G., Shang, T., Zhang, W. and Cao, X.Y. 2011. Application of improved fuzzy comprehensive evaluation method in water quality assessment. J. Environmental Engineering, 29(6): 120-127.

Guo, X.B., Qi, T., Li, H. and Zeng, Y. 2012. Evaluation of water environmental quality in Beijing country parks based on fuzzy comprehensive evaluation method. Journal of Capital Normal University, 33(1): 57-61.

Han, X.G., Huang, T.L. and Chen, X.Z. 2013. Improved fuzzy synthetic evaluation method and its application in raw water quality evaluation of water supply plant. Acta Scientiae Circums Tantiae, 33(5): 1514-1518.

Hou, J.X. 2012. The evaluation of regional water environment based on Plum Luo Pollution Index method - Take Manas River basin as an example. J. Inner Mongolia Water Resources, 5: 8-9.

Kou, W.J. 2013. Application of modified fuzzy comprehensive evaluation method in the evaluation of groundwater quality. South-to-North Water Transfers and Water Science & Technology, 11(2): 71-73.

Liu, C.H., Xu, L.G. and Gao, H.Y. 2010. River water quality evaluation method and its research progress. Journal of Hohai University, 38(2): 290-293.

Song, K., Zhao, C., Zhang, L., Zhu, A.Y. and Wu, C.W. 2013. Fuzzy comprehensive assessment on water qualify of *Larimichthys crocea* mariculture areas at Dongji. Oceanologia Etlimnologia Sinica, 44(2): 383-386.

You, Y.X., Cao, G.Z., Xiao, Z.K. and Zhang, L. 2012. Application of fuzzy comprehensive evaluation in water quality assessment of Guichi stream segment downstream of Yangtze River. Water Conservancy Science and Technology and Economy, 18(4): 54-56.