Extension Multi-factorial Evaluation Method on Water Quality Early-warning

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Abstract Extension multi-factorial evaluation method was used in water quality early-earning in Yincungang River based on MATLAB. The results showed that water quality in summer was safe, while that in other three seasons were in pre-warning state with the order of winter > spring > autumn.

Key words Extension multi-factorial evaluation; Water quality early-warning; MATLAB

In recent years, with the rapid development of social economy in Taihu area, large amount of industrial wastes and living sewage flew into Taihu. The high amount of nitrogen, phosphorus and potassium permanganate index are the reason why the water quality in Taihu is poor. Therefore, the scientific evaluation on the water quality of influents is significantly important to the accurate evaluation of water quality, which is the key to improve the general environment in Taihu.

For many years, although traditional single factor evaluation method can fully reflects the influence of each evaluation factor on standard value, it is disputable to use the worst factor to represent the entire water quality. The extension multifactorial evaluation method is the subject for solving contradiction[2]. Since the foundation in 1980s, factors such as water environment quality evaluation and air quality evaluation won wide application[3-4]. Extension multi-factorial evaluation method was used in water quality early-earning in Yincungang River based on MATLAB so as to realize the study of water quality pre-warning system.

1 Extension multi-factorial evaluation model

The extension multi-factorial evaluation model can be divided into six steps: characteristic field, unit, matter element, factor weight, relevance and evaluation standard level[5]. The pre-warning evaluation of water quality uses triad $R = (N, C, V)$, among which N is the evaluation unit, C is the combination of evaluation factor, and V is the standard combination of evaluation.

1.1 The foundation of characteristic field R_0 There are m water quality pre-warning evaluation standards N_1, N_2, …, N_m. The factor field of the corresponding evaluation standard was $[a_{ij}, b_{ij}]$. Hence, the extension multi-factorial evaluation field R0 of water quality pre-warning was as follow:

$$R_0 = \begin{bmatrix} N & N_1 & N_2 & \cdots & N_m \\ c_1 & [a_{11}, b_{11}] & [a_{12}, b_{12}] & \cdots & [a_{1m}, b_{1m}] \\ c_2 & [a_{21}, b_{21}] & [a_{22}, b_{22}] & \cdots & [a_{2m}, b_{2m}] \\ \vdots & \vdots & \vdots & \vdots & \vdots \\ c_n & [a_{n1}, b_{n1}] & [a_{n2}, b_{n2}] & \cdots & [a_{nm}, b_{nm}] \end{bmatrix} \quad (1)$$

N_i standards for the *j-th* water quality pre-warning evaluation standard; c_i standards for the ith water quality pre-warning evaluation factor; $v_{ij} = [a_{ij}, b_{ij}]$ means the c_j raneg of the i^{th} water quality pre-warning evaluation factor.

1.2 The field R_p The field Rp is as follow:

$$R_P = (P, C, V_P) = \begin{bmatrix} P & c_1 & [a_{1p}, b_{1p}] \\ & c_2 & [a_{2p}, b_{2p}] \\ & \vdots & \vdots \\ & c_n & [a_{np}, b_{np}] \end{bmatrix} \quad (2)$$

In the formula, P stands for the pre-warning evaluation standard of water quality. $[a_{ip}, b_{ip}]$ stands for the range of evaluation factor c_i.

1.3 Determination of evaluation material element R_d

$$R_d = \begin{bmatrix} P & c_1 & v_1 \\ & c_2 & v_2 \\ & \vdots & \vdots \\ & c_n & v_n \end{bmatrix} \quad (3)$$

In the formula, v_i stands for the measured value of c_i.

1.4 Weight of evaluation factors Considering the objectivity of water quality and the influence of factors on water quality, pollution method was applied [6]. The weight coefficient was calculated based on the influence of each evaluation factor on water environment.

$$\overline{S}_{ij} = \frac{1}{m}\sum_{j=1}^{m} S_{ij} \quad (4)$$

$$W_i = \frac{C_i}{\overline{S}_{ij}} \quad (5)$$

$$\overline{W}_i = \frac{W_i}{\sum_{i=1}^{n} W_i} \quad (6)$$

In the formula, S_{ij} represents the jth evaluation standard of

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ith evaluation factor, mg/L. $\overline{S}_{ij}$ is the mean value of the ith evaluation factor. W_i was the indication weight coefficient of the ith evaluation factor, $W_i \geqslant 0 (i = 1, 2, \cdots, n)$, $\sum_{i=1}^{n} W_i = 1$; $\overline{W}_i$ stands for the Normalized weight, $\sum_{i=1}^{n} \overline{W}_i = 1$.

1.5 Correlation $\rho(v_i, v_{ij}) = |v_i - \frac{1}{2}(a_{ij} + b_{ij})| - \frac{1}{2}(b_{ij} - a_{ij})$ (7)

$$\rho(v_i, v_{ip}) = |v_i - \frac{1}{2}(a_{ip} + b_{ip})| - \frac{1}{2}(b_{ip} - a_{ip}) \quad (8)$$

$$K_j(v_i) = \begin{cases} \dfrac{\rho(v_i, v_{ij})}{\rho(v_i, v_{ip}) - \rho(v_i, v_{ij})} & v_i \notin v_{ij} \\ \dfrac{-\rho(v_i, v_{ij})}{|v_{ij}|} & v_i \in v_{ij} \end{cases} \quad (9)$$

$$K_j(p) = \sum_{i=1}^{n} W_i K_j(v_i) \quad (10)$$

Here, $K_j(p)$ stands for the correlation of evaluation factor c_i of matter-element.

1.6 Grade level of evaluated matter-element Here, $K_{j0}(p)$ stands for the standard level of matter-element. j^* stands for the eigenvalue of matter-element.

2 Extension of multi-factorial evaluation

Take Yincungang River as an example. Water quality pre-warning evaluation standard system was constructed to study the water quality pre-warning grade based on MATLAB7.1.1 software.

2.1 Determination of evaluation factor and standard Evaluation factor was constructed: C = {COD_{Mn}, ammonia nitrogen, total phosphorus}. The water quality was monitored from January 1 to December 31, 2011 in accordance to the *Groundwater Environment Quality Standard* (GB3838 – 2002). The result of single factor (Table 1) suggested that the water quality in Yincun was the worse V level because of ammonia nitrogen in spring; water quality in summer and autumn was the III level and the water quality in winter was the V level.

Table 1 Evaluation result of single factor of water quality in Yincungang

Season	COD_{Mn}	Ammonia nitrogen	Total phosphorus	Evaluation result
Spring	III	Worse V	III	Worse V
Summer	III	III	III	III
Autumn	III	III	III	III
Winter	III	V	IV	V

Considering the evaluation grade of the safety of water environment and ecological environment[7], five grades were divided as safe, quite safe, pre-warning, moderate-warning and heavy warning. In response to the requirement of the division of the function of water environment, the national standard of *Groundwater Environment Quality Standard* (GB3838 – 2002) value and online automatic monitor were considered to build the pre-warning evaluation standard system (Table 2).

Table 2 Extension multi-factorial evaluation standard of water quality pre-warning mg/L

Evaluation factor	Safe	Quate safe	Pre-warning	Moderate warning	Heavy warning
GOD_{Mn}	3.0	5.0	8.0	12.5	20.0
Ammonia nitrogen	0.325	0.750	1.250	1.750	10.000
Total phosphorus	0.06	0.15	0.25	0.35	2.00

2.2 Determination of factor weight The weight of each factor in Yincungang was calculated. According to Table 3, the weight of ammonia nitrogen was the largest one, 0.459 0, while the weight of COD_{Mn} was the smallest, 0.239 7.

Table 3

Evaluation factors	W_i	$\overline{W}_i$
COD_{Mn}	0.709 5	0.239 7
Ammonia and nitrogen	1.358 4	0.459 0
Total phosphorus	0.891 7	0.301 3

2.3 Extension pre-warning evaluation and MATLAB realization As a kind of programming software, MATLAB improves the efficiency by avoiding complicated mathematic calculation and it is widely applied in the modern mathematic evaluation[8]. Based on MATLAB7.1.1, program realization formula 9 – 14 was formed to get the correlation of extension pre-warning evaluation and eigenvalue j (Table 4). As shown in Table 4, the correlation was 0.073 95, 0.14540, 0.23016, 0.00055 in spring, summer, autumn, and winter respectively, which fell into the category of pre-warning, safe, pre-warning and pre-warning state. The order of pre-warning degree was winter, spring and autumn. Compared with traditional single factor evaluation method (Table 1), the extension pre-warning level of water quality in summer was safe and the single factor evaluation result was in the III level, while the extension pre-warning level of water quality in spring was in pre-warning level and its single evaluation result was worse V, which suggested poor water quality in Yincungang River. However, the evaluation result of single factor was largely affected by ammonia nitrogen. Results suggested that the result of single factor was more scientific. Experiments proved that each evaluation factor in autumn belonged to III level, but they were not any potential threats. The water quality extension pre-warning system being in pre-warning state showed potential threat in autumn. The water quality in winter was in pre-warning state, and the eigenvalue in winter 3.246 46 higher than that in autumn (2.669 59), which indicated that the pre-warning situation in winter was much worse than that in autumn.

3 Conclusions

Extension multi-factorial evaluation method was used in water quality early-earning in Yincungang River based on MATLAB, so as to evaluate the water quality and to improve the water quality in the estuary of Taihu Region.

Table 4 Evaluation result of water quality extension pre-warning grade

Season	Correlation					j^*	*Evaluation result*
	Safety	Quite safe	Pre-warning	Moderate warning	Heavy warning		
Spring	-0.412 70 39	-0.268	0.073 95	-0.197 41	-0.239 43	3.40955	*Pre-warning*
Summer	-0.328 55	0.145 40	-0.076 44	-0.441 80	-0.612 41	2.339 32	*Quite safe*
Autumn	-0.366 63	-0.09409	0.23016	-0.30302	-0.51307	2.66959	*Pre-warning*
Winter	-0.405 77	-0.252 82	0.000 55	-0.160 35	-0.24645	3.24646	*Pre-warning*

Compared with traditional single factor evaluation method, the extension pre-warning evaluation can effectively reflect different preference of same pre-warning system. Results displayed that the water quality in Yincungang in spring, summer, autumn and winter were in pre-warning, safe, pre-warning and pre-warning state, and the pre-warning in winter was much worse than that in autumn.

The water quality extension pre-warning system can effectively reflect the potential threat of matter-element and can avoid the influence of extreme factors. The single factor evaluation result suggested that each evaluation factor in autumn belonged to III level, but they were not any potential threats. The water quality extension pre-warning system being in pre-warning state showed potential threat in autumn. The water quality in winter was in pre-warning state, which avoid from getting worse under the influence of ammonia nitrogen.

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in the overall agricultural output.

(3) This paper evaluates the sustainable use of agricultural land in Zhoukou City from economy, society and ecology. The results show that the use of agricultural land has achieved initial success in terms of economic sustainability, but in terms of ecological sustainability and social sustainability, it is at a low level; the sustainable use index shows the great vitality and development potential of agricultural system; unsustainability is reflected in considerable input of chemical fertilizer and pesticide, and simple agricultural output structure.

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