Evaluation of Water Quality of Key Sections of Yangtze River Based on Matter Element Analysis

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Abstract. The Yangtze River is the largest river in China. The quality of its water not only directly affects the safety of drinking water for residents, but also it is an important and far-reaching impact on China's ecological environment and economic development. Selecting the water quality monitoring data of the Yangtze River key section of China's ecological environment ministry with surface water environment quality standard in 2017. By the aid of matter-element theory analysis, the important sections of water quality of the Yangtze River are widely evaluated, and the evaluation results are compared with the fuzzy comprehensive evaluation method based on entropy weight, their comparison results are basically consistent. The study has shown that the matter-element analysis method can sort the water quality evaluation results for each monitoring section, and it more comprehensively analyses, discriminate, evaluates the object attribute level; the overall situation of water quality of the Yangtze is better, water quality grades are at grade II and above for most of the year.

1. Introduction
The Yangtze River is the largest river in China. The quality of its water not only directly affects the safety of drinking water for residents, but also it is an important and far-reaching impact on China's ecological environment and economic development, therefore, it is very important to make a scientific and reasonable comprehensive evaluation for water environment quality. At present, the water environment quality evaluation method has many species, for example, the projection pursuit classification, analytic hierarchy process and grey correlation analysis method, artificial neural network, fuzzy comprehensive evaluation method, matter-element analysis method and so on [1-3].

Water quality is a fuzzy concept, the water quality level can be regarded as a fuzzy set, and the quantification of its evaluation criteria may leave out some useful information. Moreover, the evaluation results of single evaluation index are not compatible or unrelated. In view of the shortcomings of the above evaluation process, we choose our property analysis method, this method can better overcome the problem of the evaluation results incompatibly, conduct multi-index evaluation at the same time, and have a formal process to resolve the problem and to build a matter-element model [3, 4]. According to China's ecological environment released by the week of continuous monitoring data in 2017, it evaluates the quality of the water environment with the Yangtze River the key sections as the research object and by the aid of matter-element theory analysis.
to verify the effect of the matter-element theory evaluation, its evaluation results are compared with fuzzy comprehensive evaluation based on entropy weight method.

2. Matter Element Theory Analysis Foundation[4-5]

The matter-element theory is mainly a method of researching and dealing with incompatibility issues. It combines matter element analysis with extension collection and is widely used in new product conception and design, optimization decision-making, control, identification and evaluation. The matter-element theory is mainly a method of researching and dealing with incompatibility issues, it combines matter element analysis with extension collection and is widely used in new product conception and design, optimization decision-making, control, identification and evaluation. The matter-element extension method uses the evaluation index system and its eigenvalues as matter-elements, and obtains the classical domain, the zonal domain and the correlation degree by the evaluation level and the actual measurement data, thereby establishing a quantitative comprehensive evaluation method.

The steps to establish an evaluation model are as follows:

(1) Confirming evaluation element

The basic unit of things is represented by an ordered triplet $R = (P, C, X)$, $P$ represents a thing, $C$ represents a characteristic of $P$, and $X$ represents a value obtained by $P$ regarding $C$. If $P$ is described by $n$ features $C_1, C_2, C_n$ and corresponding quantities $X_1, X_2... X_n$, it is called n-dimensional matter element:

$$ R = \begin{bmatrix} P & C_1 & X_1 \\ M & M & \\ C_n & X_n \end{bmatrix} $$

For the unit evaluated, the measured data are expressed as matter elements and are called evaluation elements.

(2) Confirming Classic Domain and Domain

Matter matrix of classical domain:

$$ R_j = (N_j, C_j, X_{j1}) = \begin{bmatrix} N_j & C_1 & X_{j1} \\ M & M & \\ C_n & X_{jn} \end{bmatrix} = \begin{bmatrix} N_j & C_1 & (a_{j1}, b_{j1}) \\ M & M & \\ C_n & (a_{jn}, b_{jn}) \end{bmatrix} $$

In the formula, $N_j$ is the standard thing and the $j$ water quality grade here; $C_i$ is the characteristic of $N_j$ and the evaluation index here; $X_{ji}$ is the value range of $C_i$ under $N_j$, $X_{ji} = (a_{ji}, b_{ji})$ is called Classic domain.

Matter matrix of the domain:

$$ R_p = (P_0, C_j, X_{p1}) = \begin{bmatrix} P_0 & C_1 & X_{p1} \\ M & M & \\ C_n & X_{pn} \end{bmatrix} = \begin{bmatrix} P_0 & C_1 & (a_{p1}, b_{p1}) \\ M & M & \\ C_n & (a_{pn}, b_{pn}) \end{bmatrix} $$

In the formula, $P_0$ is the domain matter and generally the entire water quality level, when the evaluation index seriously exceeds the standard, it is appropriately enlarged according to the monitoring value; $X_{pi}$ is the value range of $C_i$ under $P_0$, $X_{pi} = (a_{pi}, b_{pi})$ is called the domain.
(3) Correlation function calculation

Evaluation criteria correlation function:

\[
K_j(X_i) = \begin{cases} \frac{-\rho(X_j, X_{ji})}{X_{ji}} = \frac{-\rho(X_j, X_{ji})}{b_{ji} - a_{ji}} (X_i \in X_{ji}) \\ \rho(X_j, X_{ji}) - \rho(X_i, X_{ji}) (X_i \notin X_{ji}) \end{cases}
\] (4)

In the formula, \(K_j(X_i)\) is the correlation function of each evaluation factor with respect to the evaluation criteria; \(\rho(X_j, X_{ji})\) is the distance between the point \(X_i\) and the finite interval \(X_{ji}\); and \(\rho(X_j, X_{ji})\) is the distance between the point \(X_i\) and the finite interval \(X_{pi}\); \(X_i\) is the actual monitoring value of the \(i\)th evaluation factor.

The distance between point \(X_i\) and finite interval \(X_{ji}\) or \(X_{pi}\):

\[
\begin{align*}
\rho(X_j, X_{ji}) &= \left| X_j - \frac{1}{2}(a_{ji} + b_{ji}) \right| - \frac{1}{2}(b_{ji} - a_{ji}) \\
\rho(X_j, X_{pi}) &= \left| X_j - \frac{1}{2}(a_{pi} + b_{pi}) \right| - \frac{1}{2}(b_{pi} - a_{pi})
\end{align*}
\] (5)

(4) Confirm the weight of evaluation index

The weight coefficient \(w_{ji}\) of the feature \(C_i\) is confirmed by the threshold value \(X_{ji}(i = 1, 2... n)\) of the evaluation level \(N_j\) (\(j = 1, 2... m\)):

\[
w_{ji} = X_{ji}/\sum_{i=1}^{n} X_{ji}
\] (6)

(5) Calculation of correlation degree

The numerical value of the correlation degree indicates that the evaluation object meets the membership degree of evaluation criteria, the formula is:

\[
K_j(P) = \sum_{i=1}^{n} w_{ji} K_j(X_i)
\] (7)

In the formula, the value of \(K_j(X_i)\) represents the membership degree of the evaluation unit that meets a certain standard range, \(K_j(P)\) represents the correlation degree of the object entity \(P\) to be evaluated with respect to the \(j\)-th grade evaluation criteria, and \(w_{ji}\) represents the weight of each evaluation factor.

(6) Evaluation standard

If \(K_j(P) \geq 1\), it means that the water quality of the object evaluated is superior to the \(j\)-th grade standard; if \(1 > K_j(P) \geq 0\), the water quality of the object evaluated meets the \(j\)-th grade standard, and the numerical value The larger, the value is the closer to the standard upper limit value; if \(0 > K_j(P) \geq -1\), it means that the water quality of the evaluated object doesn’t meet the \(j\)-th grade standard, but it has the conditions to be converted to the first grade standard, and the numerical value is greater bigger and more easily transformed; if \(K_j(P) < -1\), it means that the water quality of the object evaluated doesn’t meet the \(j\)-th grade standard, and doesn’t have the condition to be converted into the \(j\)-th grade standard.
3. Water Quality Evaluation

3.1. Monitoring Data Sources and Data Processing

Seven key sections of the Yangtze River are chosen as research objects: Panzhihua Longdong, Chongqing Zhutuo, Yichang Nanjianguan, Yueyang Chenglingji, Jiujiang Hexi Water Plant, Anqing River Estuary, Nanjing Linshan, and they were numbered 1-7. Select seven key sections of Yangtze River and the 53 period data of annual monitoring weekly report in 2017, monthly monitoring data averages the weekly data. The indicators for monitoring and evaluation are dissolved oxygen (DO), potassium permanganate index (COD$_{Mn}$), ammonia nitrogen (NH$_3$-N), take June 2017 as an example, the monitoring data is shown in the Table 1.

Table 1. Water quality monitoring data in June 2017 (Unit: mg/L)

| NO. | Monitor sections      | DO     | COD$_{Mn}$ | NH$_3$-N     |
|-----|-----------------------|--------|------------|--------------|
| 1   | Panzhihua Longdong    | 7.312  | 1.460      | 0.144        |
| 2   | Chongqing Zhutuo      | 6.498  | 2.360      | 0.152        |
| 3   | Yichang Nanjianguan   | 7.616  | 1.720      | 0.080        |
| 4   | Yueyang Chenglingji   | 6.988  | 1.960      | 0.254        |
| 5   | Jiujiang Hexi Water Plant | 6.510 | 3.000      | 0.158        |
| 6   | Anqing River Estuary  | 6.296  | 2.740      | 0.204        |
| 7   | Nanjing Linshan       | 6.134  | 2.600      | 0.104        |

Note: the data of the brackets in the table are the data after normalization.

The evaluation data were all from the website of the Data Center of the China Ecology and Environment Ministry. The surface water environmental quality standard [6] (GB3838-2002) was used as the evaluation standard at all levels in the Table 2. The matter-element theory was used to evaluate the water environment quality. The water quality monitoring values and evaluation criteria is first normalized according [7], the processing results are the data of the brackets (See Table 1, 2).

Table 2. Index limit evaluation criteria (Unit: mg/L)

| Index  | Grade I     | Grade II    | Grade III   | Grade IV    | Grade V     |
|--------|-------------|-------------|-------------|-------------|-------------|
| DO     | 7.5(0.267)  | 6(0.467)    | 5(0.600)    | 3(0.876)    | 2(1.000)    |
| COD$_{Mn}$ | 2(0.133) | 4(0.267)    | 6(0.400)    | 10(0.667)   | 15(1.000)   |
| NH$_3$-N | 0.15(0.075) | 0.5(0.250) | 1(0.500)    | 1.5(0.750)  | 2(1.000)    |

Note: the data of the brackets in the table are the data after normalization.

3.2. Selecting Classic Domain and Domain

According to the data of the brackets in the Table 2, the normalized range of I-V corresponding to the normal range is taken as the range of classic domain; according to the data of the brackets in the Table 1 and Table 2, the normalized measured data and the range of the evaluation standard value are taken as the range of domain. By the formulas (2) and (3), the classical domain $R_j$ ($j=1, 2, 3, 4, 5$) and the domain $R_p$ of the water quality evaluation are determined (See Table 3).

Table 3. Ranges of the classic domain and the domain

|        | $R_1$       | $R_2$       | $R_3$       | $R_4$       | $R_5$       | $R_p$       |
|--------|-------------|-------------|-------------|-------------|-------------|-------------|
| DO     | (0, 0.267)  | (0.267, 0.467) | (0.467, 0.6) | (0.6, 0.867) | (0.867, 1)  | (0, 1)      |
| COD$_{Mn}$ | (0, 0.133) | (0.133, 0.267) | (0.267, 0.4) | (0.4, 0.667) | (0.667, 1)  | (0, 1)      |
| NH$_3$-N | (0, 0.075)  | (0.075, 0.25) | (0.25, 0.5)  | (0.5, 0.75)  | (0.75, 1)   | (0, 1)      |
3.3. Calculation Results

According to formulas (4) and (5), the correlation function of the evaluation factor under all levels of evaluation criteria is calculated (See Table 4). According to formulas (6) and (7), the weight coefficient value and the correlation degree of all types of evaluation water bodies for each level are calculated (See Table 5 and 6).

| Table 4. Correlation function calculation results |
|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------|
| Grade I DO | Grade II COD$_{BOD}$, NH$_3$-N | Grade III DO | Grade IV COD$_{BOD}$, NH$_3$-N | Grade V DO |
| -0.078 | 0.271 | 0.04 | 0.125 | -0.271 | -0.04 |
| -0.248 | -0.133 | -0.013 | 0.335 | 0.179 | 0.006 |
| 0.064 | 0.135 | 0.467 | -0.06 | -0.135 | -0.467 |
| -0.167 | 0.015 | -0.291 | 0.340 | -0.015 | 0.297 |
| -0.252 | -0.251 | -0.048 | 0.340 | 0.500 | 0.023 |
| -0.271 | -0.215 | -0.209 | 0.200 | 0.373 | 0.154 |
| -0.287 | -0.188 | 0.307 | 0.090 | 0.299 | -0.307 |

| Table 5. Weight coefficient value |
|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------|
| $w_{j1}$ | $w_{j2}$ | $w_{j3}$ | $w_{j4}$ | $w_{j5}$ |
| 0.561 | 0.281 | 0.158 | 0.475 | 0.254 |
| 0.475 | 0.271 | 0.254 | 0.400 | 0.333 |
| 0.400 | 0.267 | 0.333 | 0.380 | 0.328 |
| 0.380 | 0.292 | 0.328 | 0.333 |

In the Table 6, we can see that water quality of one monitoring section is Class I in June 2017, which is only the Yichang Nanjinguan; water quality of five monitoring sections is Class II, the results of the water quality ranking were Jiujiang Hexi Water Plant, Anqing River Estuary, and Yueyang Chengling, Ikeji, Chongqing Zhiyu, Panzhuhua Longdong; grade III water quality monitoring section is only Nanjing Linshan. But the water quality of the Yangtze River was better.

| Table 6. Correlation degree calculation results |
|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------|
| Sections NO. | Grade I DO | Grade II COD$_{BOD}$, NH$_3$-N | Grade III DO | Grade IV COD$_{BOD}$, NH$_3$-N | Grade V DO |
| 1 | -0.043 | -0.0242 | -0.377 | -0.506 | -0.807 |
| 2 | -0.179 | 0.209 | -0.234 | -0.582 | -0.733 |
| 3 | 0.148 | -0.184 | -0.617 | -0.731 | -0.825 |
| 4 | -0.135 | 0.233 | -0.413 | -0.508 | -0.749 |
| 5 | -0.219 | 0.303 | -0.354 | -0.549 | -0.711 |
| 6 | -0.245 | 0.235 | -0.316 | -0.529 | -0.673 |
| 7 | -0.165 | 0.0458 | 0.374 | -0.573 | -0.270 |

Using the same method, other months' evaluation values can be obtained (See Table 7). It shows that, (1) the water quality of 7 monitoring sections is stable in 12 months, and the water quality is better, most of which were grade I or II. The water quality of the monitoring section 7 showed a level of grade IV (July) in 12 months, while the other months were grade II or III, and II was the majority. The water quality of monitoring sections 2, 4 and 5 is basically stable at grade II; Monitoring section 1 and 3 water quality performance is better (grade I or II). (2) In summer (may to September), water quality is worse than other season, the water quality of monitoring cross section 7 has only a grade IV, other monitoring cross section of the water quality stability in a class I or class II, grade III is relatively small. In short, the whole river section of the Yangtze River has a better overall water quality in 2017.
Table 7. Water quality evaluation results per month in 2017

| Months | Section No. | Evaluation Grade |
|--------|-------------|------------------|
| 1      | II II I I III II I I I I I I | 1 2 3 4 5 6 7 8 9 10 11 12 |
| 2      | II II II II II II II II II II II | |
| 3      | II II I I II I I I I II II II II | |
| 4      | II II II II II II II II II II II II | |
| 5      | II III II II II III II II II II II II | |
| 6      | II II II II II II III II II II II II | |
| 7      | II II II II II III IV III II II II III | |

3.4. Evaluation Test

On the monitoring data averaged of the year 53 issues, the matter-element model is exploited to evaluate water quality of the Yangtze River, meantime, the entropy weight- fuzzy comprehensive evaluation method is used for evaluating the quality of the water [8], two methods of evaluation of the results are shown in table 8.

Table 8. Comparison of evaluation results

| Section No. Method                      | 1 2 3 4 5 6 7 |
|----------------------------------------|---------------|
| Matter-element evaluation              | I II I II II II III |
| Entropy weight fuzzy evaluation        | I II I II II III III |

According to the comparison of the evaluation results in table 8, the two methods are basically consistent for the evaluation results of each monitoring section, it indicates that the physical model can better evaluate the water quality of the Yangtze River.

4. Conclusion

Water quality monitoring data of key section of Yangtze river are analyzed by using the evaluation of matter-element theory, and the evaluation results of the method and the evaluation results of fuzzy comprehensive evaluation were compared, it indicates that The water quality in the Yangtze river is generally good; the matter-element theory can comprehensively analyze and judge evaluation objects belonging to a some level, and the water quality evaluation results can be sorted, it offers more abundant information, makes judgment more accurate, provides reliable scientific basis for quality evaluation of water.

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