Application of Integrated Black-odorous Index Method on Black-odorous Prediction for Urban River in Nanning

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Abstract. In this paper, the integrated black-odorous index method was used to predict the degree of black-odorous for the urban rivers (such as Shibu, Keli and Naping River) which locate in the north shore of the Yongjiang River in Nanning. The results showed that the accuracy of the integrated black-odorous index method was 98.10% compared with the prediction method from guideline. The integrated black-odorous index method was a good characterization of the black-odorous index for urban rivers in Nanning. In order to eliminate the influence of extreme value, a correction factor (named $b$) is added to limit the extreme value. The accuracy of the prediction was increased to 99.05% after the correction proved that this method is effective.

Introduction

To continuously improve the city's water ecosystem, the State Council issued a "Water Pollution Prevention Action Plan" in 2015, requiring the black-odorous to be eliminated from the water body by the end of 2017[1]. Nanning City, actively promote the 18 rivers black-odorous water body management work, A landmark step has been taken on the road to "water city in southern China".

The Guidelines for the Improvement of Urban Black Matter Water (referred to as the "Guide"), for the extent of black-odorous water is divided into "black-odorous mild" and "severe black-odorous" levels, It mainly through the water Transparency ($SD$), Dissolved Oxygen ($DO$), Redox potential ($ORP$), Ammonia ($NH_3-N$) four water quality indicators to determine. As the "Guide" judgment method is susceptible to accidental factors and geographical effects, the comprehensive black stink index method was used to evaluate the black-odorous degree of Naping River, Shibu River and Keli River which stand in the north bank of Yongjiang River, hope to provide the method support for the evaluation and management of black-odorous water in Nanning city.

Integrated Black-odorous Index Method

Nemero Environmental Quality Index

The Nemero index is a kind of weighted multi-factor environmental quality index with extreme value, it can be used to evaluate the degree of water pollution, highlighting the contribution of pollutants with the largest pollution index to environmental quality[5], but the evaluation results are susceptible to extreme pollution. The express is:

$$PI_i = \sqrt{\frac{P_{i,max}^2 + P_{i,ave}^2}{2}}$$

(1)
\[ P_i = \frac{C_i}{L_{ij}} \]  

(2)

In the formula: The internal merlot pollution index of PI -I index; the score of Pi-I single index; the measured value of \( C_i \) - I single index; the j-class standard concentration of \( L_{ij} \) - I single index.

**Integrated Black Odor Index Model**

Refer to "Guide", a comprehensive index method black smelly water into the city is not black-odorous, mild and severe black-odorous three black-odorous level, Black-odorous grade level defined characteristic index \( \Pi = 0 \) when no black-odorous, \( \Pi = 10 \) black smelly when severe limit, and when the water depth is less than 25 cm, the indicator is 40% of the water depth. See Table 1,2.

| Table 1. The black-odour’s grades of integrated black-odour index method. |
|---------------------------------|-----------------|-----------------|-----------------|
| **Transparency(cm)**           | \( \geq 25 \)   | 10~25           | \( \leq 10 \)   |
| **Dissolved Oxygen(mg/L)**      | \( \geq 2 \)    | 0.2~2           | \( \leq 0.2 \)  |
| **Redox potential(mV)**        | \( \geq 50 \)   | -200~50         | \( \leq -200 \) |
| **Ammonia(mg/L)**              | \( \leq 8 \)    | 8~15            | \( \geq 15 \)   |

| Table 2. Correspondence between the degree of black-odorous and the \( \Xi \) value. |
|-------------------------------|-----------------|-----------------|-----------------|
| **Black-odorous grading**     | Not black-odorous| Black-odorous mild| Severe black-odorous |
| **Characteristic index**      | \( 0~1 \)       | 1~2             | 2~10            |

The formula 1 and 2 and Table 2, to obtain black-odorous index of transparency, dissolved oxygen black-odorous index, index redox potential black-odorous and ammonia black smelly linear expression with their index measured value, respectively, formulas 3, 4, 5 and 6.

\[
P_{\text{sa}} = \begin{cases} 
0, & C_i \geq 25 \\
\frac{1}{15} C_i + \frac{8}{3}, & 10 < C_i < 25 \\
-\frac{4}{5} C_i + 10, & 0 \leq C_i < 10 
\end{cases}
\]  

(3)

\[
P_{\text{DO}} = \begin{cases} 
0.2, & C_i \leq C_{im} \\
\frac{-5}{9} C_i + \frac{19}{9}, & 0.2 < C_i < 2 \\
-40 C_i + 10, & 10 \leq C_i < 0.2 
\end{cases}
\]  

(4)

\[
P_{\text{ORP}} = \begin{cases} 
0.50, & C_i \leq C_{im} \\
\frac{1}{250} C_i + \frac{6}{5}, & -200 < C_i < 50 \\
\frac{8 C_i + 200}{200 + C_{im}} + 2, & C_{im}' \leq C_i \leq -200 
\end{cases}
\]  

(5)

In the formula, \( C_{im} \) is the temperature corresponding to the sample water saturated dissolved oxygen content, that is the limit of water oxidation, \( C_{im}' \) limit to the reduction of water.
To find reference: $C_{im}=811mV$, $C_{im}'=-413mV$; then when $-413 \leq C_i \leq -200$, $P_i = \frac{-8}{213} C_i - \frac{1174}{213} \tag{6}$

To put the monitoring data of all the sampling points of the river into the corresponding values of the $C_i$ in the formulas 3, 4, 5 and 6 respectively, that can get SD, DO, ORP and NH3-N black-odor index grading standard value.

**Comprehensive Black Odor Index Weight Coefficient $W_i$**

The Nemero Index emphasizes the effect of significant pollution on water pollution, therefore needs to increase the weighting factor. General use of comprehensive black odor index method using the evaluation index exceeded the rate to determine the weight $\tag{6}$. The weight of the pollution index and the weighting coefficient are calculated as follows:

$$I_i = \frac{C_i}{S_j} \tag{7}$$

$$W_j = \frac{C_j / S_j}{\sum_{i=1}^{n} C_i / S_i} = \frac{I_j}{\sum_{i=1}^{n} I_i} \tag{8}$$

$$\sum_{i=1}^{n} W_i = 1 \tag{9}$$

In formula: $I_i$ is a dimensionless number; $C_i$ is the i-th measured value evaluation of species; $S_i$ is the i-th arithmetic mean value of the quality index criteria; For the smaller the value the more serious pollution indicators such as ORP, SD and DO, is calculated by a reciprocal of formula 7; when found negative ORP contained, exceeded the rate is calculated using the absolute values.

**Calculation and Correction of Comprehensive Black Odor Index**

Integrated black-odor index ($PI$) by calculating the black-odor index and index weight of each single individual to get the weight $W_i$, the expression is as follows:

$$PI = W_{SD} \cdot P_{SD} + W_{DO} \cdot P_{DO} + W_{ORP} \cdot P_{ORP} + W_{NH3-N} \cdot P_{NH3-N} \tag{10}$$

In formula: $P_{SD}$, $P_{DO}$, $P_{ORP}$, $P_{NH3-N}$ were SD, DO, ORP, NH3-N black-odorous index; $W_{SD}$, $W_{DO}$, $W_{ORP}$, $W_{NH3-N}$ are the weights of SD, DO, ORP, NH3-N black-odorous index.

Due to the combined effects of black-odor index vulnerable to extreme values, so the proposed correction factor $b$, used to correct the cross-section water quality measured data appear extreme value of the comprehensive black odor index value. The expression is as follows:

$$b = \frac{I_j}{I_i} \tag{11}$$
In formula: $I_j$ is the measured extreme value of the standard rate; $\bar{I}_i$ is the measured value in addition to the extreme value of the excess rate outside the standard rate.

Therefore, a comprehensive expression of black-odorous index $PI_X$ revised as follows:

$$PI_X = bPI$$

(12)

**Evaluate the Degree of Black-odorous Water Composite Index Method**

The original black odor index method proposed a variable factor $a$, with the comprehensive black odor index grading limit $PI'$ multiplied by the variable factor $a$, to obtain a practical classification standard value $PI'$, the expression:

$$PI' = aPI_f$$

(13)

$$a = 0.3(1 + n)$$

(14)

**The Total Expression of Black-Odorous Index Comprehensive Evaluation Model:**

$$\begin{align*}
PI &= W_{SD} \cdot P_{SD} + W_{DO} \cdot P_{DO} + W_{ORP} \cdot P_{ORP} + W_{NH_3-N} \cdot P_{NH_3-N} \\
PI' &= 0.3 \times (1 + n)(W_{SD} \cdot P_{SD} + W_{DO} \cdot P_{DO} + W_{ORP} \cdot P_{ORP} + W_{NH_3-N} \cdot P_{NH_3-N})
\end{align*}$$

(15)

In formula: $PI'$ integrated value of the standard black-odorous evaluation index classification section; $a$ is the variable factor. $n$ is the number of the average index less than 0.2 weight items.

Finally, comparing the PI with the $PI'$ value, the results of the evaluation of the degree of water quality are obtained.

**Application of Comprehensive Index Method in Black-odorous River Evaluation in Nanning**

**Basic Situation of River and the River Black-odorous Single Index in Nanning**

Shibu River and Keli River are both on the upstream north shore in the urban reach Yongjiang River, Naping River is located in the downstream north shore in the urban reach Yongjiang River, they are the first class tributary of Yongjiang River, and the water quality are inferior V class.

According to the formula 7, 8, 9, it can calculate the index weight coefficient of the single black stink index of each river. Three river black-odorous index average individual weight coefficient is basically $SD>ORP>DO>\text{NH}_3-N$, showed significant organic pollution characteristics.

**River Monitoring Sections of Water Quality Parameters**

Between October and November in 2015, three water quality tests were carried out on three of the same sampling points along the river, and according to the three monitoring data of the river, to make a single black-odorous index calculation, then we can get the classification standard of individual black stink index of each river. For example, the water quality of the Keli River is very good, $DO$, $ORP$ and $NH_3-N$ indicators are not black-odorous, does not reach values of black-odorous mild and severe black-odorous.

**Each Black-odorous River Comprehensive Index**

According to 14, can be obtained evaluation results of grading the degree of comprehension of each rivers black-odorous. The results showed that, Water pollution is more serious Shibu River and Naping River black-odorous degree of comprehensive evaluation grading standard value is
relatively low, and the water quality pollution is relatively light Keli River black-odorous degree of comprehensive evaluation grading standard is relatively high. The evaluation result is consistent with the actual pollution degree of three rivers.

Results and Analysis

Comprehensive evaluation index display of black-odorous, the water quality of 1 to 4 monitoring sections in Shibu River is not black-odorous, 5 to 8 monitoring sections is severe black-odorous; the water quality of 1 to 18 monitoring sections in Keli River is not black-odorous; the water quality of 1 to 4 monitoring sections in Naping River is not black-odorous, 5 to 13, 15 to 19 and 22 to 24 monitoring sections is black-odorous mild, 14 and 20 to 21 monitoring sections is severe black-odorous.

The results of the evaluation of the "Guide" show that the evaluation results of all the sections of the Shibu River and Keli River are consistent with the results of the comprehensive black-odorous index method, Comprehensive evaluation of the results of these black-odorous index level of two black-odorous river accuracy rate of 100%. Inconsistency as follows: the water quality for Naping River No.15 monitoring sections is severe black-odorous, No.21 monitoring sections is black-odorous mild. After processing with the correction factor b, the integrated black-odorous index value in No.21 monitoring section is 1.265, less than the severe black-odorous standard value of 1.697, greater than the not black-odorous standard value of 0.348. Re-judged as mild black-odorous, consistent with the results of the "Guide" judgment.

Conclusion

(1) Through the study of the extent of black-odorous for Nanning Yongjiang the north shore of the river Shibu River, Keli River and Naping River, the result is that, The after correction evaluation results of the comprehensive black-odorous index compared with the "Guide" method, the accuracy rate is 98.10%. This shows that the integrated black-odorous index method can be a good detection of Nanning City, the river black-odorous index, it can be used for black-odorous river level evaluation.

(2) The comprehensive black-odorous index method after correcting by the factor b can further reduce the influence of the extreme value on the comprehensive black-odorous index method, which can improve the accuracy rate to 99.05%, But can’t solve the problem the grading standard is partial large when the water quality partition is not complete.

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