Application of Water Quality Evaluation in the Cotai City Ecological Reserve in Macau: Taking the Single Factor Index Evaluation Method as an Example

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Abstract. This paper uses a single-factor index evaluation method to evaluate the water quality of the Cotai Ecological Reserve in Macau. Water quality evaluation is a necessary way to rationally renovate the water environment. In this paper, the average dissolved oxygen, average total nitrogen, average total phosphorus and BOD5 in the water environment of the ecological protection zone are used as the evaluation indicators of water quality. The analysis results show that the average dissolved oxygen index can maintain the requirements of water function zoning throughout the year. The average total nitrogen and BOD5 index exceeded the standard seriously. Therefore, the water quality index of the ecological zone needs to be improved.

In recent years, in order to further improve the quality and safety of the water environment, the Macau Special Administrative Region government has optimized the treatment measures of various sewage treatment plants in Macau, and has strengthened the quality monitoring of the water environment by issuing environmental quality standards for surface water. However, according to the report of the Macao Environmental Protection Agency, in the 2019 Macao coastal water quality evaluation, the non-metal evaluation index is higher than the standard value, which is mainly affected by inorganic nitrogen and active phosphate. In terms of eutrophication, in 2019, the eutrophication index of the Outer Harbor and Zhuwan area increased last year, while the eutrophication index of the remaining monitoring points declined to varying degrees.

In order to further understand the water quality environment in Macau, this article uses the Macau Cotai Ecological Reserve as a data sample collection point to determine the average dissolved oxygen, average total nitrogen, average total phosphorus and BOD5 in the ecological reserve as water quality evaluation indicators. And use a single factor index evaluation method to detect whether the water quality exceeds the standard among the above indicators, and then provide a scientific basis for Macao's water environment management in the ecological protection zone.

1. Brief introduction of single factor index evaluation method

1.1. Single factor water quality index $P$
$P$ consists of an integer, 2 or 3 significant digits after the decimal point, expressed as

$$P_i = X_1 \times X_2 \times X_3$$ (1)
X1: The water quality category of the i-th water quality indicator;
X2: The location of the monitoring data in the X1 water quality change interval is determined according to the principle of rounding the formula;
X3: The comparison result of the water quality category and the functional zone classification category is the pollution degree of the evaluation index.

1.2. Confirmation of X1
Since X1 represents the water quality category of the water quality index, the water quality monitoring data of the ecological protection area can be compared with the national standard. Its meaning is: X1=1, which means that the water is Class I water; X1=1, that the water is Type I water; X1=2, indicating that this type of water is Type II water; X1=3, indicating that this type of water is Type III water; X1=4, indicating that this type of water is Type IV water; X1=5, indicating this type of water is Class V water.

1.3. Confirmation of X2
According to the surface water environmental quality standard (GB3838-2002), the mass concentration of dissolved oxygen decreases as the water quality category increases, and all indicators except water temperature and pH increase with the increase in temperature, so the water quality label index can be calculated based on the dissolved oxygen index.

1.3.1. Dissolved oxygen. The mass concentration of dissolved oxygen will decrease as the water quality category increases. The X2 of the dissolved oxygen index can be determined according to the result in Equation 2 and rounded off.

\[ x_2 = \frac{\beta_{\text{up}} - \beta}{\beta_{\text{up}} - \beta_{\text{low}}} \times 10 \]  

In the formula, \( \beta \) represents the measured mass concentration of dissolved oxygen; \( \beta_{\text{up}} \) represents the upper limit of the mass concentration of dissolved oxygen in the k-th type of water, k = X1; \( \beta_{\text{low}} \) represents the lower limit of the mass concentration of dissolved oxygen in the k-th type of water, k = X1.

1.4. X1. Confirmation of X2

1.4.1. When the water quality is between Class I and Class V, the calculation of the general indicators is as follows:

\[ x_1 \cdot x_2 = k + \frac{\beta_i - \beta_{\text{low}}}{\beta_{\text{up}} - \beta_{\text{low}}} \]  

Among them, \( \beta_i \) represents the measured concentration of the i-th index; \( \beta_{\text{up}} \) the upper limit of the i-th index in the k-type water quality standard interval; \( \beta_{\text{low}} \) represents the lower limit of the i-th index in the k-type water quality standard interval; k=1, 2, 3, 4, 5, determined by monitoring data and national standards.

1.4.2. When the water quality is lower than or equal to Grade V water, the calculation of the general indicators is as follows:

\[ x_1 \cdot x_2 = 6 + \frac{\beta_i - \beta_{\text{up}}}{\beta_{\text{up}}} \]  

1.5. Confirmation of X3

\[ X3 = X1 - f_i \]  

In the formula, X3 needs to judge three different situations to obtain different values. Its main significance is to determine whether the single water quality category is inferior to the water
environment function zone category. If the water quality category is better than or reaches the functional zone category, $X_3=0$; if the water quality category is inferior to the functional zone category and $X_2$ is not zero, then $X_3 = X_1 - f_i$; if the water quality category is inferior to the functional zone category and $X_2$ is zero, then $X_3 = X_1 - f_i - 1$, where $f_i$ is the category of water environment functional area.

2. Selection of sampling
In this paper, sampling and analysis of water quality in the Ecological Reserve of Cotai City, Macau, the sampling indicators are the average dissolved oxygen, average total nitrogen, average total phosphorus, and BOD5.

**Table 1.** Water quality data of Cotai Ecological Reserve

| Data time | Average dissolved oxygen mg/L | Average total nitrogen mg/L | Average total phosphorus µg/L | BOD5 mg/L |
|-----------|-------------------------------|----------------------------|-------------------------------|------------|
| 2020/01   | 8.60                          | 2.08                       | 0.10                          | 3.55       |
| 2020/02   | 8.80                          | 1.92                       | 0.06                          | 3.67       |
| 2020/03   | 9.90                          | 2.67                       | 0.13                          | 4.36       |
| 2020/04   | 8.60                          | 1.50                       | 0.06                          | 5.05       |
| 2020/05   | 9.50                          | 2.38                       | 0.20                          | 4.90       |
| 2020/06   | 10.30                         | 2.01                       | 0.10                          | 4.47       |
| 2020/07   | 11.27                         | 14.25                      | 0.16                          | 6.65       |
| 2020/08   | 13.35                         | 1.48                       | 0.14                          | 6.93       |
| 2020/09   | 13.05                         | 1.19                       | 0.23                          | 6.70       |
| 2020/10   | 12.80                         | 1.80                       | 0.17                          | 6.33       |
| 2020/11   | 11.56                         | 2.88                       | 0.82                          | 5.74       |
| 2020/12   | 12.99                         | 2.20                       | 0.11                          | 6.62       |

Data source: Environmental Protection Bureau of Macao Special Administrative Region

3. Evaluation results
According to the data in Table 1, the single factor index evaluation method is used to obtain the results of various indicators. See Table 2 for details.

**Table 2.** Calculation results of single-factor water quality labeling index $P$

| Data time | Water Environment Function Zone Target | Average dissolved oxygen mg/L | Average total nitrogen mg/L | Average total phosphorus µg/L | BOD5 mg/L |
|-----------|----------------------------------------|------------------------------|----------------------------|-----------------------------|-----------|
| 2020/01   | II                                     | 1.30                         | 6.04                       | 1.00                        | 3.51      |
| 2020/02   | II                                     | 1.10                         | 6.03                       | 2.50                        | 3.61      |
| 2020/03   | II                                     | 1.60                         | 6.34                       | 3.31                        | 4.12      |
| 2020/04   | II                                     | 1.30                         | 5.02                       | 2.50                        | 6.43      |
| 2020/05   | II                                     | 1.30                         | 6.24                       | 4.02                        | 4.42      |
| 2020/06   | II                                     | 1.90                         | 6.04                       | 3.01                        | 4.22      |
| 2020/07   | II                                     | 1.10                         | 12.14                      | 4.92                        | 6.33      |
| 2020/08   | II                                     | 1.20                         | 4.92                       | 3.41                        | 6.33      |
| 2020/09   | II                                     | 1.20                         | 4.32                       | 4.32                        | 6.33      |
| 2020/10   | II                                     | 1.30                         | 6.13                       | 3.71                        | 6.33      |
| 2020/11   | II                                     | 1.10                         | 6.44                       | 7.05                        | 6.43      |
| 2020/12   | II                                     | 1.30                         | 6.14                       | 3.11                        | 6.33      |

3.1. Result analysis
Through the analysis of Table 2, $X_3$ in the Dissolved Oxygen Water Quality Marking Index is 0 for the whole year of 2020, indicating that dissolved oxygen can meet the requirements of water function zoning. However, the values of total nitrogen and BOD5 water quality labeling index $X_3$ are not zero throughout
the year. The above analysis shows that total nitrogen and BOD5 have serious excesses in each month of 2020. The total phosphorus water quality index X3 was 0 in January, February and April, and it exceeded the standard in other months.

4. Conclusion and suggestion
In this paper, a single-factor water quality index evaluation method is used in the Cotai Ecological Reserve in Macau. The analysis results show that the average total nitrogen and BOD5 in the ecological reserve exceed the indicators. The average total phosphorus is in the whole year. Months that exceed the standard also account for the majority, indicating that the water quality of the ecological reserve still needs to be managed. Part of the water source purification measures are used to improve the water quality and ecological balance in the ecological reserve.

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