Water Quality Assessment and Comparison before and after a Promotion Project of Rivers in a Park, China

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Abstract. Composite Index Method is an accurate, fast and convenient method for evaluating eutrophication of water bodies. It was used in this paper to analyze and evaluate the changes of the water quality, mainly changes of the eutrophication of the rivers in the park, China, before and after the promotion project. The results showed that through the promotion project, the eutrophication of the water has been greatly decreasing, water bodies are clear and transparent, the ecosystem is stable, and the water quality indicators are good.

1. Introduction
Water quality assessment is the basis for landscape water body, and has always been the concern of environmental protection workers and water conservancy scholars. Study of water quality assessment began in the mid-1960s by foreign scholars, and developed in the 1970s[1]. More than ten models or methods have been proposed so far, mainly including Grading Method, Analytic Hierarchy Process, Fuzzy Comprehensive Evaluation, Grey Clustering Analysis, Composite Index Method.

Grading Method is based on quantitative and qualitative analysis, focusing on evaluating the correlation assessment of the control results of subjective factors[2]. The advantage is that quantitative assessment could be made in the absence of sufficient statistical and original data. Analytic Hierarchy Process was put forward by an American Operational researcher T.L.Satty in the 1970s[3], a multi-objective decision assessment technology combining qualitative and quantitative analysis. It needs the support of experts. If the indicators given by experts are not reasonable, the assessment results will be inaccurate[4]. Fuzzy Comprehensive Evaluation is a comprehensive assessment method based on fuzzy mathematics[5]. With the characteristics of clear and systematic results, this method is commonly used to solve problems which are fuzzy and difficult to quantify, and is suitable for solving all kinds of non-deterministic problems[6]. Fuzzy mathematics is widely used in the assessment of water eutrophication. Grey Clustering Analysis is extended by a Chinese professor Julong Deng according to the concept of “grey box”[7], and makes full use of some known conditions to make evaluation and prediction. The quality level of landscape water is uncertain, and it is difficult to determine the comprehensive condition of water quality through a certain index. The grey cluster analyzes the water quality category by integrating the weight of different indexes, which has a high credibility[8-9]. Composite Index Method assumes that the contribution of each index to water quality is basically the same and uses the weighted arithmetic average value of the standard index of each evaluation index to calculate. The result is a relative water quality index value, which is related to the difference of evaluation standard[10].

The evaluation results of different methods are different, but the correlation is good. In the actual application process of Grading Method, if the score of a certain parameter is significantly lower or
higher than other parameters, the score value indicates that the change of the parameter is affected by the eutrophication, and other factors have a greater influence on the parameter, so the parameter should be deleted. The parameters that are often deleted are more interfered by human factors and affect the accuracy of the results. In the calculation, it is found that the calculation procedure of the Analytic Hierarchy Process, Fuzzy Comprehensive Evaluation and Grey Clustering Analysis is cumbersome and time consuming, and it is not as simple as the comprehensive nutrition index method. Therefore, it is feasible to select Composite Index Method as a unified method for evaluating eutrophication.

This paper aims to use Composite Index Method to analyze and evaluate the changes of the water quality, mainly changes of the eutrophication of the rivers in the park, China, before and after the promotion project.

2. Materials and Methods

2.1. Study area
Gongqing Forest Park is located in Yangpu District of Shanghai, east of Huangpu River and west of Jungong Road. Shanghai Gongqing National Forest Park is a special park with forest as its main landscape. It has planted more than 200 species of trees, totaling more than 300,000. The park is divided into two parks, the North Park covers an area of 1,631 mu, known as the Gongqing Forest Park. The South Park covers an area of 239.6 acres and is called Wanzhu Garden. The style of the North and South Parks varies. The North Park focuses on forest scenery, with hilly lakes and grasslands, while the South Park is a small bridge with a view of the South. The geographical location of Gongqing Forest Park is shown below (Fig.1.).

![Fig.1. Location map of Gongqing Forest Park](image)

The current state of the park water system consists of a large lake area and a number of small river courses. Due to the increasing number of tourists, the construction of drainage facilities is lagging behind, and the water pollution problem of the water system in the park is becoming increasingly prominent, which seriously affects the overall landscape environment of the park and has a certain impact on the safety of the water recreation project in the park. Through water quality monitoring, it was found that the overall water pollution of the park was serious. Most of the water bodies in the park were inferior to Class V [11] water, and all water bodies did not meet the Class IV recreational water standards. Combined with the analysis of the flow conditions of the water system and the location of the pollution source, there are two main reasons for the deterioration of the water quality in the park: First, the river has poor fluidity, the river silt has serious organic pollution, the aquatic ecosystem is destroyed, and the water body has poor self-cleaning function; The situation that sewage water is discharged into the river directly increases the pollution of the park water body.
2.2. Project overview
From June 10, 2018 to December 31, 2018, the water quality of the park was evaluated by analyzing the water quality before, during, after and after the construction of the Wanzhuyuan water body of Shanghai Gongqing Forest Park. Environmental promotion projects improve water quality. The main test indicators include: pH, transparency, dissolved oxygen, five-day biochemical oxygen demand, chemical oxygen demand, ammonia nitrogen, total nitrogen, total phosphorus and chlorophyll a. The sampling point diagram is shown below (Fig. 2.):

![Sampling point diagram](image)

Fig.2. Distribution of sampling points in Gongqing Forest Park

Nine samples were taken at each sampling point, and a total of 27 samples were taken from three sampling points. Sampling 1 time before construction from June 6 to June 30, 2018, a total of 27 samples. During the construction period from July 1st to September 30th, 2018, the water plants were sampled once after planting, and sampled 1 time before completion acceptance, a total of 54 samples. The maintenance period from October 1st to December 31st, 2018, is sampled twice a month for 6 times, for a total of 162 samples. A total of 243 samples were analyzed.

2.3. Water quality index analysis method

2.3.1. pH. The pH was measured by a glass electrode method, and the pH was obtained by measuring the electromotive force of the battery. The battery typically consists of a saturated calomel electrode as the reference electrode and a glass electrode as the indicator electrode. At 25 ° C, the potential difference changes by 59.16 mV for every unit change in pH in the solution, and is thus directly indicated by the pH reading on the instrument. The temperature difference has a compensating device on the instrument.

2.3.2. Transparency (SD). The transparency was measured using a cross black and white measuring disc, and the length of the rope was measured as the value of transparency when the measuring disc was sunk to the depth where the black and white border was not visible to the naked eye.

2.3.3. Turbidity. Turbidity refers to the degree of hindrance produced by a solution when light passes through, including the scattering of light by the suspended matter and the absorption of light by the solute molecules. The turbidity was measured using a turbidimeter.

2.3.4. UV254/272. UV254/272 is the absorbance of some organic substances in water at 254 nm/272 nm wavelength, reflecting the naturally occurring humus macromolecular organics in water and the aromatic compounds containing C=C double bonds and C=O double bonds.

2.3.5. TOC. TOC total organic carbon, measured by TOC analyzer, is a comprehensive indicator of the total amount of organic matter in water in terms of carbon content. TOC can be used directly to indicate the total amount of organic matter, so it is used as an important reference for assessing the degree of organic contamination in water. The working principle of the TOC analyzer is to first
oxidize the carbon of the organic matter in the water to carbon dioxide, eliminate the interference factor and then measure it by the carbon dioxide detector, and then convert the carbon dioxide gas content into the concentration of the organic matter in the water through data processing.

2.3.6. Ammonia nitrogen. Ammonia nitrogen refers to nitrogen present in the form of free ammonia (NH$_3$) and ammonium ions (NH$_4^+$). It was measured using an ammonia nitrogen colorimeter.

2.3.7. TN. A large amount of domestic sewage, farmland drainage or nitrogenous industrial waste water is discharged into the water body, so that the content of organic nitrogen and various inorganic nitrogen compounds in the water increases, and the algae multiply and consume dissolved oxygen in the water, which deteriorates the quality of the water body and appears eutrophication. Total nitrogen is one of the important indicators for measuring water quality and is measured using a TOC analyzer.

2.3.8. TP. Total phosphorus is the total content of phosphorus in water and is one of the indicators for measuring the organic matter content of water. Excessive phosphorus content can cause excessive growth of algae plants, water bodies are eutrophic, water blooms or red tides occur, and water body balance is destroyed. The measurement of TP was carried out by molybdenum antimony anti-spectrophotometry.

2.3.9. DO. The dissolved oxygen content of natural water depends on the balance of water and oxygen in the atmosphere. The saturated content of dissolved oxygen is closely related to the partial pressure of oxygen in the air, atmospheric pressure, and water temperature. The DO was measured using a dissolved oxygen meter.

2.3.10. COD. COD is a chemical method for measuring the amount of reducing substances in a water sample that need to be oxidized. The chemical oxygen demand reflects the degree of contamination of the water by reducing substances. The COD is measured using a heat digestor and a colorimeter.

2.3.11. BOD$_5$. BOD$_5$ is an important indicator of the amount of dissolved oxygen consumed by microbial metabolism to indirectly indicate the degree of contamination of water by organic matter. Determined by dilution and inoculation.

2.3.12. Chlorophyll a (chla). Chlorophyll is an important photosynthetic pigment in plant photosynthesis. By measuring the phytoplankton chlorophyll, the primary producers of water bodies can be mastered, and the chlorophyll a content can be used as an indicator to measure the degree of eutrophication of lakes. The determination of chlorophyll a was carried out by spectrophotometry.

2.4. Composite Index Method
   The composite index formula is

   $$ TLI(\Sigma) = \sum_{j=1}^{m} W_j \cdot TLI(j) $$

   In the formula, $TLI(\Sigma)$ represents the comprehensive nutritional status index, $TLI(j)$ represents the nutritional status index of the jth parameter, $W_j$ represents the weight of the nutritional status index of the jth parameter.

   With chla as the reference parameter, the normalized correlation weight of the jth parameter is calculated as

   $$ W_j = \frac{r_{ij}^2}{\sum_{j=1}^{m} r_{ij}^2} $$

   $r_{ij}$ is the correlation coefficient between the jth parameter and the reference parameter chla, and m is the number of evaluation parameters.
The relationship between chla and other parameters of Chinese lakes $r_{ij}$ and $r_{ij}^2$ are shown in the table below.

Table 1. Correlation between partial parameters of Chinese lakes and chla, $r_{ij}$ and $r_{ij}^2$ values[10]

| Parameter | chla | TP  | TN  | SD  | COD |
|-----------|------|-----|-----|-----|-----|
| $r_{ij}$  | 1    | 0.84| 0.82| -0.83| 0.83 |
| $r_{ij}^2$| 1    | 0.7056| 0.6724| 0.6889 | 0.6889 |

The nutritional status index is calculated as follows

\[
(1) TLI(chla) = 10(2.5 + 1.086 \ln chla) \\
(2) TLI(TP) = 10(9.436 + 1.624 \ln TP) \\
(3) TLI(TD) = 10(5.453 + 1.694 \ln TN) \\
(4) TLI(SD) = 10(5.118 - 1.941 \ln SD) \\
(5) TLI(COD) = 10(0.109 + 2.661 \ln COD)
\]

3. Results and Discussion

3.1. Changes in the degree of eutrophication of water bodies

We applied the comprehensive nutrition index method to evaluate the eutrophication of lakes from June 2018 to April 2019. The calculation results are shown in Table 2.

According to the principle of relevance, operability, simplicity and scientificity, five indicators including chla, TP, TN, SD and COD are selected from the many factors affecting lake eutrophication. Uniform indicators for eutrophication evaluation.

In order to illustrate the eutrophication status of the lake, a series of consecutive numbers of 0-100 are used to grade the nutritional status of the lake:

- Oligotropher: $TLI(\sum) < 30$;
- Mesotropher: $30 \leq TLI(\sum) < 50$;
- Eutropher: $TLI(\sum) \geq 50$;
- Light eutropher: $50 < TLI(\sum) \leq 60$;
- Middle eutropher: $60 < TLI(\sum) \leq 70$;
- Hyper eutropher: $TLI(\sum) \geq 70$.

In the same nutritional state, the higher the index value, the more nutritious it is.

Table 2. Statistics of water quality of parks from June 2018 to April 2019

| Date       | COD (mg/L) | TP (mg/L) | TN (mg/L) | chla (mg/m³) | SD (m) | TLI | Eutrophic level       |
|------------|------------|-----------|-----------|--------------|--------|-----|-----------------------|
| 2018/6/22  | 113.04     | 0.48      | 0.96      | 21.74        | 0.627  | 75.01| Hyper eutropher       |
| 2018/7/25  | 66.55      | 0.22      | 0.82      | 3.12         | 0.722  | 63.45| Middle eutropher      |
| 2018/9/10  | 76.07      | 0.08      | 0.84      | 2.13         | 0.75   | 59.85| Light eutropher       |
| 2018/10/25 | 72.7       | 0.15      | 0.5       | 0.03         | 0.75   | 47.65| Mesotropher           |
| 2018/11/28 | 65.7       | 0.13      | 0.49      | 0.03         | 0.75   | 46.66| Mesotropher           |
| 2018/12/21 | 30.33      | 0.13      | 0.53      | 0.03         | 1.33   | 41.08| Mesotropher           |
| 2019/3/13  | 15.33      | 0.13      | 0.53      | 0.07         | 1.33   | 40.20| Mesotropher           |
| 2019/4/19  | 15.37      | 0.11      | 0.55      | 0.05         | 1.33   | 38.85| Mesotropher           |

According to the analysis data, TLI before treatment is relatively high, meaning that the water eutrophication is serious and conducive to the reproduction of aquatic plants, so the water body appears cloudy green. After the treatment in July, the water body basically reached Light eutropher level, the growth and reproduction of aquatic plants decreased, and the water body clarity increased. During the maintenance period from September 18 to the present, the water body nutrition index has further declined, indicating that the water body has reached a good state. It is apparent from the above table that the TLI and eutrophication level has been greatly decreasing, meaning that the effect of the promotion project on reducing eutrophication of water is remarkable. The first sampling of TLI was high, indicating that the algae concentration in the lake water is higher and the degree of
Eutrophication is higher. After the treatment, the concentration of TLI decreased significantly during the construction period from July to September, and the concentration of chlorophyll a was very low during the maintenance period. TLI remained low during the curing period. Corresponding to the analysis of TN, TP, and chlorophyll a, it can be seen that the decrease in the concentration of the eutrophication index is reduced due to the content of algae in the water. It can be seen that after the treatment, the phenomenon of eutrophication of water has been greatly improved.

3.2. Other important water quality indicators

Data analysis was carried out on eight water quality indicators measured in three lakes. The data measured at 9 points in each lake were averaged for water quality assessment analysis to analyze the treatment effect. Detailed data and analysis are as follows.

As can be seen from the above Fig.3., the first water sample has higher turbidity and lower transparency, indicating that the water quality of the water before the treatment of Gongqing Park is poor, and the pollution is serious, which affects the ornamental nature of the park. The second water sample was higher in transparency and turbidity than the first time, indicating that after the initial treatment of the lake water in July, the water body was purified, the sensory of the naked eye was improved, and the water treatment effect was initially effective. Because of the planting of water plants in August, some lake water was drained, the water level was lowered, and the water level was less than 0.75m. Therefore, the transparency could not be measured in the third and fourth sampling in September and October. October is the curing period and the turbidity is further reduced. In December, the water level of the water body returned to the normal height, the water depth was more than 1.33m, the water body was clear, the turbidity was low, and the transparency was high. The turbidity and transparency of the water samples collected in March and April 2019 were at a good level, and the water quality was stable.

Analyze the UV254, UV272 and TOC data analysis charts above, and compare the water samples eight times in a longitudinal direction. It can be seen that the UV 254/272 and TOC values are higher before the first sampling, ie, the water body treatment, indicating that the organic matter concentration in the water body is high, the water body There is organic pollution, which may lead to deterioration of the quality of the water environment, harm to the survival of aquatic organisms, and water pollution that threatens the health of humans and animals. After the pollution control of sewage interception and sewage interception, planting water plants and other engineering treatment, the organic matter concentration in the water body decreased in July and September, and remained at a relatively stable level, indicating that the water grass has a certain purification effect on the water body, and the treatment has good effects. During the maintenance period from October to December, the concentration of organic matter in water decreased further and stabilized at a low level, indicating that
the water treatment effect was good and achieved certain results. In March and April of 19, the concentration of organic matter in the water remained at a low level, indicating that the water quality of the water was in a stable state.

It can be seen from the Fig.3 that the first sampled DO has a lower COD, indicating that the organic pollution in the lake water is more serious, and the dissolved oxygen in the water body is more likely to cause water environment problems. After the treatment, the COD decreased significantly in July and September, the \( \text{BOD}_5 \) decreased, and the DO increased, indicating that after the treatment, the total amount of organic matter in the water body decreased and the water quality improved. During the curing period in October, the COD was relatively stable, but it still did not reach the Class III standard for surface water, and the reason for the slight decrease in DO may be related to the decrease in temperature, and the lower temperature resulted in lower dissolved oxygen. After December, the water body COD and \( \text{BOD}_5 \) were further reduced, and they have reached the Class III standard for surface water.

4. Conclusion
Composite Index Method is an effective, simple and accurate method for evaluating eutrophication of water bodies. It is apparent that the TLI and eutrophication level has been greatly decreasing, meaning that the effect of the promotion project on reducing eutrophication of water is remarkable. The turbidity and transparency of the water samples collected after the promotion project were at a good level, and the water quality was stable. In March and April of 19, the concentration of organic matter in the water remained at a low level, indicating that the water quality of the water was in a good state. After December, the water body COD and \( \text{BOD}_5 \) were further reduced, and they have reached the Class III standard for surface water.

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