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Application and comparison of four assessment methods for water quality of Sancha Lake in Central Sichuan Province, China

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ABSTRACT

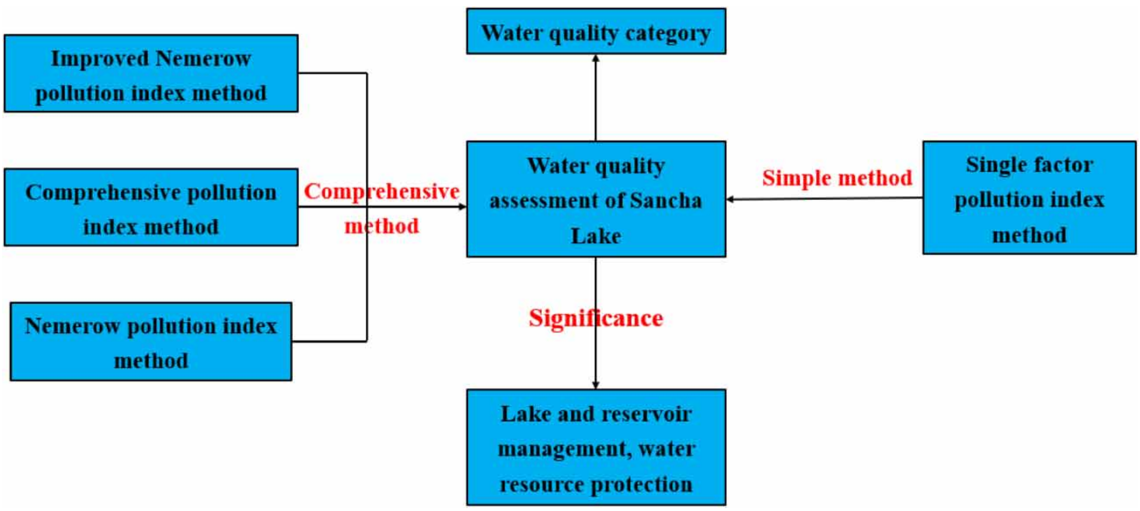
In order to analyze and compare the characteristics and applicability of different water quality evaluation methods applied to lake water quality evaluation, four monitoring sections were set up in Sancha Lake in 2019, 2020, and 2021, and 20 water quality parameters were selected. The single factor index method, the comprehensive pollution index method, the Nemerow pollution index method, and the improved Nemerow pollution index method were used to comprehensively evaluate water quality. The research results showed that the single factor index evaluation method is simple to operate and can quickly determine the water quality category by identifying the worst single water quality indicator. The comprehensive pollution index method and the Nemerow pollution index method determine the degree of water pollution based on the numerical values representing the overall pollution level of the representative water body. The evaluation results showed that except for the evaluation results of the single factor evaluation method with categories II and III, the results of other evaluation methods were all category I, indicating that the water quality was good.

Key words: comprehensive pollution index method, single factor evaluation, water quality evaluation

HIGHLIGHT

- The single factor index method, the comprehensive pollution index method, the Nemerow pollution index method, and the improved Nemerow pollution index method were used to comprehensively evaluate water quality.

GRAPHICAL ABSTRACT



1. INTRODUCTION

Water resources are important materials for human survival and precious resources that cannot be replaced in industrial and agricultural production and economic development (Wang *et al.* 2016). Lakes and reservoirs are important freshwater resource reservoirs on Earth and important strategic resources in China. As an important part of the terrestrial hydrosphere and a participant in the natural water cycle process, lakes and reservoirs have multiple functions such as flood regulation, water quality purification, and climate regulation (Liu *et al.* 2022). They are also an important guarantee for the ecological environment and play an important role in maintaining regional ecological security (Cichoń 2017). Currently, water quality evaluation of lakes and reservoirs is a fundamental work for water environment management (Saeed & Hashmi 2014). Only by using reasonable water quality evaluation methods can the current water quality status of the water body be accurately reflected, providing a scientific basis for water pollution control and water environment management, and further promoting the rational utilization of the resources of lakes and reservoirs.

At present, there are more methods used at home and abroad to evaluate the water quality condition of rivers and lakes and reservoirs, commonly used are the single factor index evaluation method based on grading criteria (Huang 2020; Liu *et al.* 2020; Peng *et al.* 2020), the comprehensive pollution index method (Chen *et al.* 2017; You *et al.* 2021), and the Nemerow pollution index method (Yin *et al.* 2023), and also such as principal component analysis based on multivariate statistical analysis (Liu *et al.* 2022), gray correlation method (Du *et al.* 2022), and analysis of variance (Xia *et al.* 2022), and artificial neural network method (Zhang *et al.* 2022) and support vector machine (Zhou *et al.* 2021) based on data mining and pattern recognition between data. In recent years, researchers have used different water quality evaluation methods to evaluate the water quality of rivers and lakes. Yin used the single factor index method, the principal component analysis, the Nemerow pollution index method, and the Shannon-Weaver diversity index method to conduct a comprehensive evaluation of Dongting Lake water quality (Yin *et al.* 2023); Cui applied the single factor index method, the comprehensive pollution index method, the pollutant sharing rate, the flux analysis, and other methods to evaluate the water quality of Hongze Lake COD_{Mn}, NH_3-N, TP, and TN. The water quality evaluation and pollutant change trend analysis were carried out for four indexes (Cui *et al.* 2021); Shan used the comprehensive water quality identification index method to analyze and evaluate the water quality of the inlet and outlet of Shifosi Reservoir from 2009 to 2015 (Shen 2019); Liu selected the fuzzy comprehensive evaluation method for the comprehensive evaluation of the water quality of Sancha Lake, and found that the main pollutants in Sancha Lake are TN and TP, and in many years, they are more than the standard of Class III water quality requirements (Liu 2012).

Sancha Lake is located in Sancha Town, Janyang City, Chengdu City, Sichuan Province, which is entrusted to the management of Chengdu High-tech Zone as a whole, called High-tech East Zone, 60 km from Tianfu Square in the north and 32 km from Janyang City in the northeast, and is the core area of 'Two Lakes and One Mountain', the new five major tourist areas in Sichuan Province. There are numerous large and small weirs and ditches and creeks used for agricultural irrigation within the scope of Sancha Lake; Sancha Lake is the production and living drinking water source of Sancha Township, with abundant water resources. Sancha Lake's basic water quality belongs to a class of water quality, local areas have two or three types of water quality pollution situations, at present, many pollution prevention and control and environmental management measures to make the pollution of the Sancha Lake watershed tends to decline mode, and has achieved obvious results. However, water eutrophication with nitrogen and phosphorus pollution is the prominent cause (Li *et al.* 2019). In terms of the water environment, the water quality of Sancha Lake has not yet reached the good water quality required by the tourism landscape water system in some areas, and the water body of the east shore lake shows a mild eutrophic state. Dealing with water quality problems and major pollutants and establishing a good water ecological environment is the key to the sustainable operation of Sancha Lake. The previous studies on the Sancha Lake mainly focused on water body eutrophication and sediment migration change patterns (Jia *et al.* 2015), while there were fewer studies on the evaluation of various monitoring indicators, so the single factor pollution index method, the integrated pollution index method, and the Nemerow pollution index method were used to study a number of indicators in order to obtain a more scientific and reasonable basis for the management of the Sancha Lake.

2. RESEARCH AREAS AND METHODS

2.1. Research areas and data

Sancha Lake has a humid subtropical monsoon climate with an average annual temperature of 15.2–16.9 °C and an average annual precipitation of 786.5 mm. Sancha Lake is a large reservoir lake of the Dujiangyan

Longquanshan Irrigation Project, with a lake area of 27 km^2, a storage capacity of 227 million m^3, an average water depth of 8.3 m, and a maximum water depth of 32.5 m. The water of Sancha Lake is mainly drawn from the Minjiang River, and the water intake is located at the north end of Sancha Lake. The south trunk canal led by Zhangjiayan Reservoir is the main water channel of Sancha Lake. The south trunk canal extends southward, which can replenish water to Lao Ying Reservoir in Ziyang City, and can also merge into Jiangxi River and finally flow into Tuojiang River. The lake's shore is tortuous and complex, with a perimeter of 240 km, 18 km from north to south and 7 km from east to west. This study evaluated the water quality of Sancha Lake using annual averages of monitoring indicators for 2019 and 2020 and averages of testing indicators from January to June 2021 for the two intakes, the center of the lake, the end of the lake, and the whole lake. Monitoring indicator values are shown in Supplementary Tables S1–S3. The sample map of Sancha Lake is shown in Figure 1.

2.2. Sampling method and determination of water samples

In this study, water samples were collected in 2019, 2020, and the first half of 2021 according to the Technical Specifications Requirements for Monitoring of Surface Water and Waste Water (HJ/T91-2002). The sampling frequency is once a month, 12 times a year, and the water quality index data is averaged. This specification is suitable for water quality monitoring of rivers, lakes, reservoirs, and other water bodies. According to the methods specified in Table 4 of the Environmental Quality Standards for Surface Water (GB3838-2002), the 20 basic water quality parameters included in the standards were determined in the laboratory. In addition, for the determination of COD, potassium dichromate ($K_2Cr_2O_7$) was chosen as the oxidizing agent for the determination, as this method is easy to operate, highly accurate, and suitable for all types of water bodies.

2.3. Water quality evaluation method

2.3.1. Single factor pollution index method

The single factor pollution index method is the Environmental Quality Standards for Surface Water (GB3838-2002) in the river water quality evaluation method, is also China's environmental protection departments commonly used evaluation method, and the calculation results are simple and intuitive. The single factor pollution index method is the simplest environmental quality index. Each pollution factor is evaluated separately, and their respective over-standard multiples are obtained by statistics. The water quality category of each index was determined according to the multiple of exceeding the standard, and the water quality category of the most polluted index in the monitoring section was taken as the water quality category of the section (Hua *et al.* 2016). However, this method is easy to cause one-sided evaluation results, which cannot reflect the overall situation of lake water quality (Noori *et al.* 2019), and cannot objectively reflect the environmental quality level of surface water or its environmental functions. The calculation formula is:

$$P_i = \frac{C_i}{C_{oi}} \tag{1}$$

In the formula, P_i represents the single pollution index of indicator i; C_i is the measured concentration (mg/L), C_{oi} is the standard concentration (mg/L), which is the Category III water standard in the Environmental Quality Standards for Surface Water (GB3838-2002).

2.3.2. Comprehensive pollution index method

The comprehensive pollution index method is a weighted composite calculation of the indices of each pollution indicator of the single pollution index, resulting in a value representing the degree of pollution of the water body, so as to evaluate the pollution status of water quality (Lu & Zhang 2009). The comprehensive pollution index is obtained on the basis of the single factor evaluation method. It can qualitatively reflect the comprehensive pollution degree of lake water and divide the grade according to the relevant standards. It is an important evaluation method of water environment quality (Zeng *et al.* 2021). The comprehensive pollution index method overcomes the limitations of the single indicator evaluation of water bodies, and multiple indicators make the evaluation

Figure 1 | (a) Relative location of monitoring points. (b) Location of sampling points in the 1# water intake, 2# water intake, and lake tail. (c) Location of sampling points in the lake center.

more comprehensive and systematic. The calculation formula is:

$$P_c = \frac{1}{n}\sum_{i=1}^{n} P_i \tag{2}$$

In the formula, P_c represents the comprehensive pollution index of the water body; n is the number of monitoring indicators participating in the evaluation; and P_i is the pollution index of i indicators.

2.3.3. Nemerow pollution index method

The Nemerow index is a weighted multi-factor environmental quality index that takes into account the mean and extreme values of individual pollution indices and can highlight the role of more polluting pollutants (Xie *et al.* 2012). This method is a water pollution index (Luo *et al.* 2016) proposed by Professor N.L. Nemerow of the Syracuse University in his book *Scientific Analysis of River Pollution*. According to the measured concentration and standard value of the selected water quality index, the Nemerow pollution index and the standard index are calculated, respectively. Compared with the corresponding grade standard index, the evaluation grade can be obtained. The calculation formula is:

$$P_N = \sqrt{\frac{P_{i\,\max}^2 + P_{i\,\mathrm{ave}}^2}{2}} \tag{3}$$

In the formula, P_N represents the Nemerow pollution index; $P_{i\max}$ is the maximum value of P_i; and $P_{i\mathrm{ave}}$ is the average value of P_i.

2.3.4. Improved Nemerow pollution index method

In general, the smaller the concentration of pollution indicators in surface water quality standards, the greater the harm to water quality, which is inversely proportional to each other (Ding 2010). The traditional Nemerow pollution index method takes into account the influence of the extreme and mean values of the index pollution index on water quality, which overly highlights the more polluted indicators, without considering the influence of the weight of each indicator. In view of the shortcomings of the traditional Nemerow index method, the mean value is corrected on the basis of the original method, which avoids the disadvantages of ignoring important pollution factors and can better evaluate the overall situation of water environment quality. Therefore, the traditional formula of the Nemerow pollution index is improved (Yang *et al.* 2012). The improved Nemerow pollution index method takes into account the weights of the indicators, which can better reflect the pollution of the water body in a comprehensive manner. The calculation formula is as follows:

$$\omega_i = \frac{r_i}{\sum_{i=1}^{m} r_i} \tag{4}$$

$$r_i = \frac{S_{\max}}{S_i} \tag{5}$$

In the formula, r_i is the correlation ratio, S_i is the standard value of each pollution factor, $S_{\max}$ is the maximum standard value of the ith pollution factor, and ω_i is the weight of the ith pollution factor.

The mean values of the single factor indices of the participating evaluations were improved, and the improved formula was calculated as follows (Li *et al.* 2016):

$$P'_N = \sqrt{\frac{P_{i\max}^2 + P'^2}{2}} \tag{6}$$

$$P' = \sum_{i=1}^{n} \omega_i P_i \tag{7}$$

In the formula, P'_N represents the Nemerow pollution index; $P_{i\max}$ is the maximum value of P_i; and P' is the mean value with weights.

2.4. Data processing

Excel was used for data processing, and Origin 2021 was used for graphing.

3. RESULTS

3.1. Determination of the water quality classification standard

According to the regulations of the Chengdu Ecological Environment Bureau, the specified category of this sampling section is the Class III standard of the Environmental Quality Standards for Surface Water (GB3838-2002). According to the formula of the evaluation method, the classification standard is calculated based on the Class III water. The grading standards of three water quality evaluation methods are shown in Tables 1–3.

Table 1 | Water quality category determination based on the comprehensive pollution index method

Assessment of pollution	Water quality category	P_c
No pollution	I	≤ 0.484
Slight pollution	II	(0.484, 0.743]
Moderate pollution	III	(0.743, 1.000]
Heavy pollution	IV	(1.000, 2.417]
Serious pollution	V	>2.417

Table 2 | Water quality category determination based on the Nemerow pollution index method

Assessment of pollution	Water quality category	P_N
No pollution	I	≤ 0.786
Slight pollution	II	(0.786, 0.881]
Moderate pollution	III	(0.881, 1.00]
Heavy pollution	IV	(1.00, 7.275]
Serious pollution	V	>7.275

Table 3 | Water quality category determination based on the improved Nemerow pollution index method

Assessment of pollution	Water quality category	P'_N
No pollution	I	≤ 0.783
Slight pollution	II	(0.783, 0.792]
Moderate pollution	III	(0.792, 1.00]
Heavy pollution	IV	(1.00, 8.817]
Serious pollution	V	>8.817

3.2. Analysis of the water quality change of Sancha Lake based on the single factor pollution index method

The single factor pollution index method is used to evaluate the water quality of each sampling point of Sancha Lake, and the single factor index calculation results of each index for each year are shown in Supplementary Table S4 according to formula (1). It can be seen that the single factor index of each index is less than 1, and the overall water quality basically meets the Class III standard of the Environmental Quality Standards for Surface Water (GB3838-2002) stipulated by the Chengdu Ecological Environment Bureau.

The evaluation results in Table 4 and Figure 2 show that in 2019, the 2# water intake and lake tail among the four monitoring sections were Class I water quality, the middle of the reservoir was Class II water quality, and the 2# water intake was Class III water quality. In 2020, the 1# water intake and 2# water intake were Class I water quality, the lake tail and lake center were Class III water quality. In 2021, the monitoring results of the lake center

Table 4 | Single factor index method evaluation results

	2019		2020		2021	
Monitoring section	**Water quality category**	**Main pollutants**	**Water quality category**	**Main pollutants**	**Water quality category**	**Main pollutants**
1# water intake	III	TP	I	COD_{Cr}		
2# water intake	I	COD_{Cr}	I	COD_{Cr}		
Lake tail	I	COD_{Cr}	III	TP		
Lake center	II	DO	III	TP	III	TP
The whole	I	COD_{Cr}	III	TP	III	TP

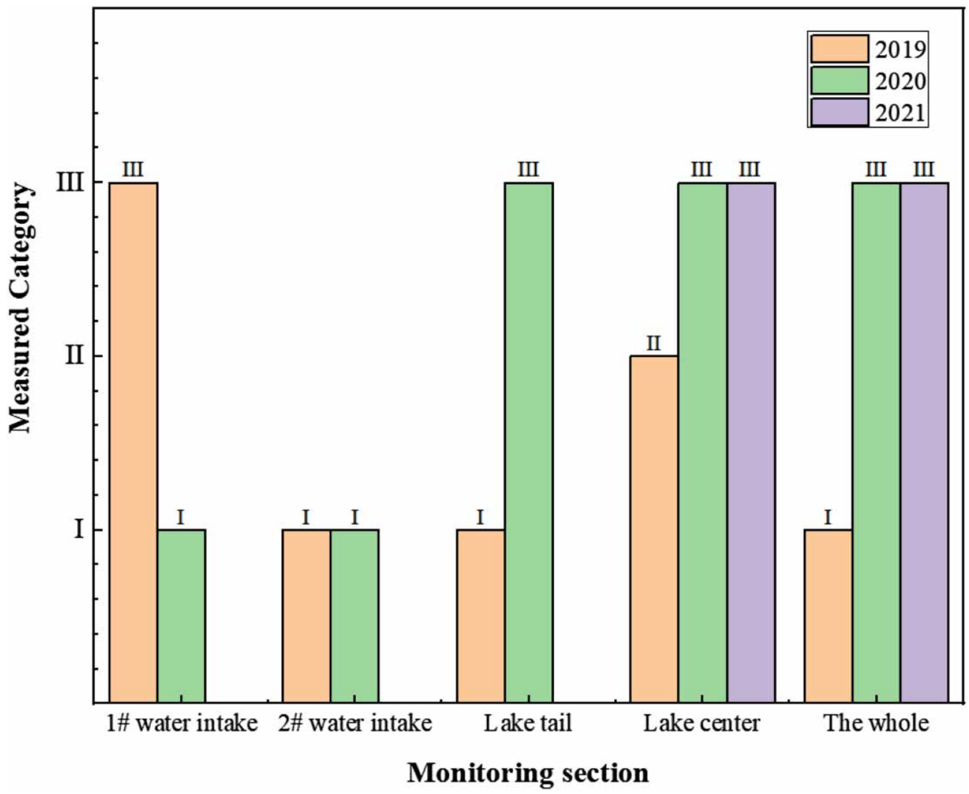


Figure 2 | Water quality category measured by the single factor pollution index method of Sancha Lake in 2019, 2020, and 2021.

were Class III water quality. Overall, in 2019, the main pollutants were concentrated in TP, COD_{Cr}, and DO; in 2020, the pollutants were COD_{Cr} and TP, and in 2021, the main pollutant was TP. The type of pollutants may be related to the development of the Sancha Lake Scenic Area for economic purposes, such as the development of rural tourism facilities.

3.3. Analysis of the water quality change of Sancha Lake based on the comprehensive pollution index method

The comprehensive pollution index method in the single factor index evaluation method is based on the individual pollution index of each indicator for the weighted average. The comprehensive response to the pollution situation of each section makes up for the shortcomings of the single factor index evaluation which emphasizes too much on one indicator. According to formula (2), the data of the four monitoring sections in the Sancha Lake are calculated, and the calculation results are shown in Figure 3. The comprehensive pollution index of each section in 2019–2021 does not change much, and is located between 0.182 and 0.224, the water quality situation is

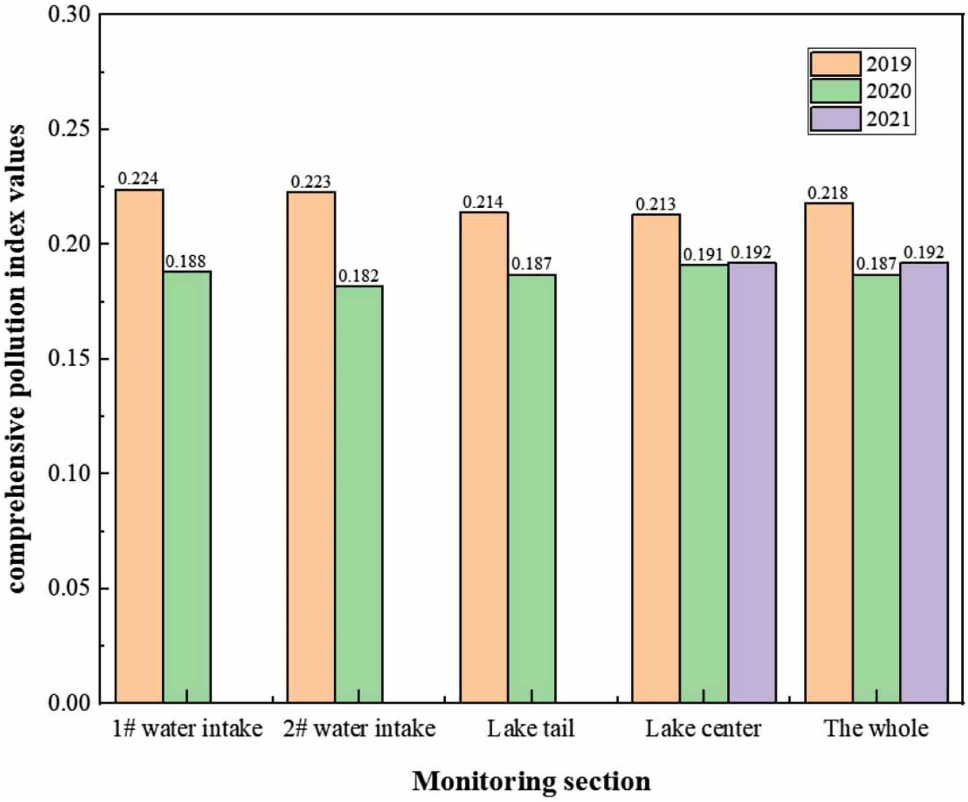


Figure 3 | Comparison of the comprehensive pollution index of various monitoring sections of Sancha Lake in 2019, 2020, and 2021.

stable, and the water quality of each section is I water quality, and the overall water quality is also I water quality, the water quality is good, compared with the grading standard table of the comprehensive pollution index method. From Figure 3, it can be seen that the pollution index of each section from 2019 to 2021 is decreasing year by year, and the water quality is getting better year by year.

3.4. Analysis of the water quality change of Sancha Lake based on the Nemerow pollution index method

The Nemerow pollution index method is based on the single pollution index of each index, and the average and highest values of the individual pollution index are selected and calculated according to the formula (3). According to Figure 4, 2019–2021 of the Nemerow pollution index between 0.445 and 0.531, against the grading standards of the Nemerow pollution index method, the water quality of each section is I water quality, the overall water quality is also I water quality, water quality is better. We can see that the Nemerow pollution index of each section decreases year by year from 2019 to 2021, and the water quality situation becomes better year by year.

3.5. Analysis of the water quality change of Sancha Lake based on the improved Nemerow pollution index method

In order to make up for the shortcomings of the Nemerow pollution index method that does not take into account the weight of each index, the improved Nemerow pollution index method is used to calculate each section. According to formula (4)–(7), the calculation results are shown in Figure 5, the pollution index of 2019–2021 is between 0.446 and 0.545. According to the grading standard of the improved Nemerow pollution index method, the water quality of each section is I water quality, and the overall water quality is also I water quality, which is good. From the figure, we can see that the pollution index of each section decreases year by year from 2019 to 2021, and the water quality situation becomes better year by year.

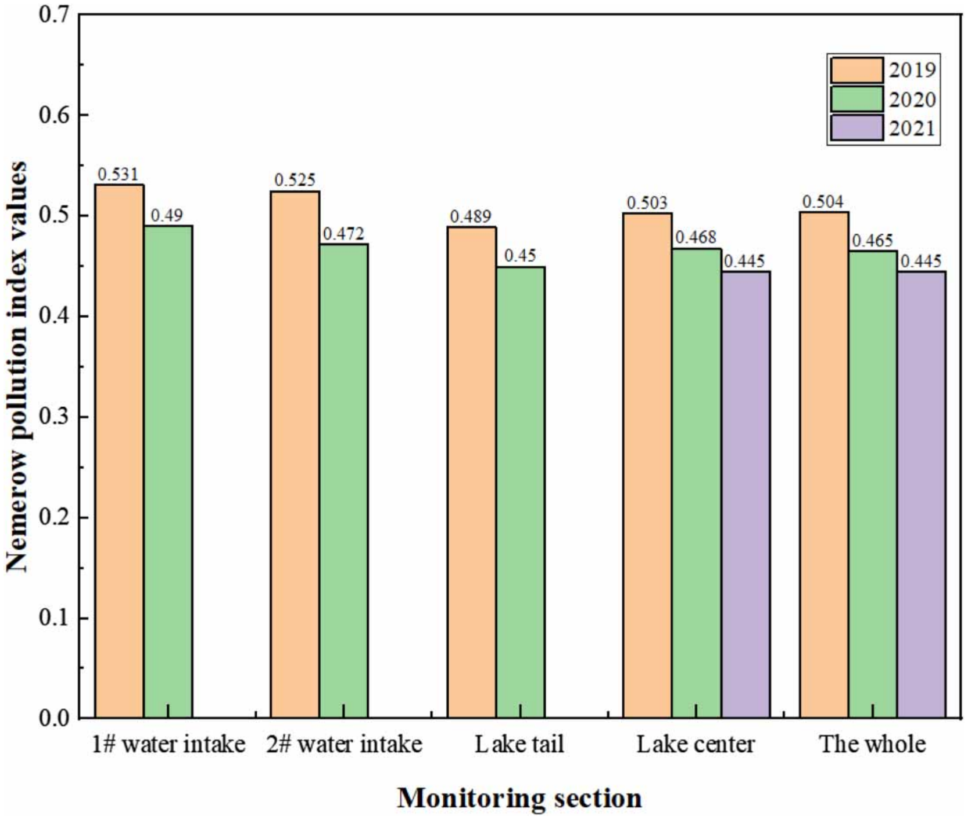


Figure 4 | Comparison of the Nemerow pollution index of various monitoring sections of Sancha Lake in 2019, 2020, and 2021.

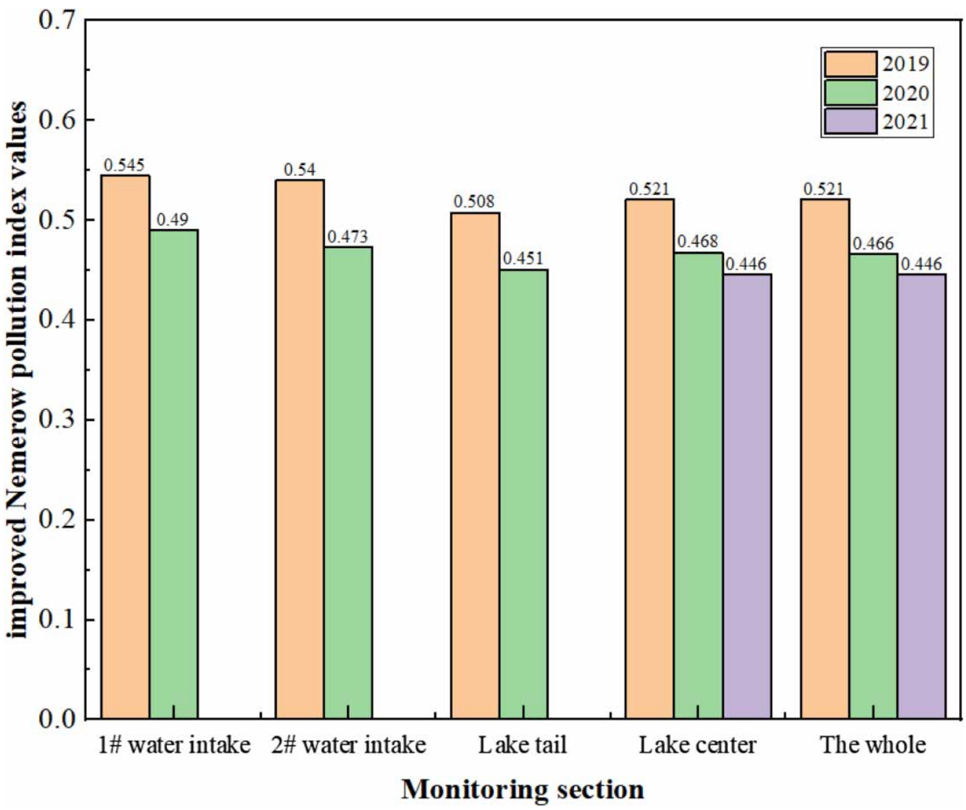


Figure 5 | Comparison of the improved Nemerow pollution index of various monitoring sections of Sancha Lake in 2019, 2020, and 2021.

4. DISCUSSION

4.1. Comprehensive comparison of evaluation results

The evaluation of each monitoring section of Sancha Lake was carried out, and the evaluation results are shown in Figure 6. The water quality category of each section obtained by the four evaluation methods except for the evaluation results of the single factor evaluation method has II and III, the results of the rest of the evaluation methods are I, which meet the requirements of water function zoning. Because the single factor index evaluation method focuses too much on the most polluted index, the evaluation results are too conservative and pessimistic.

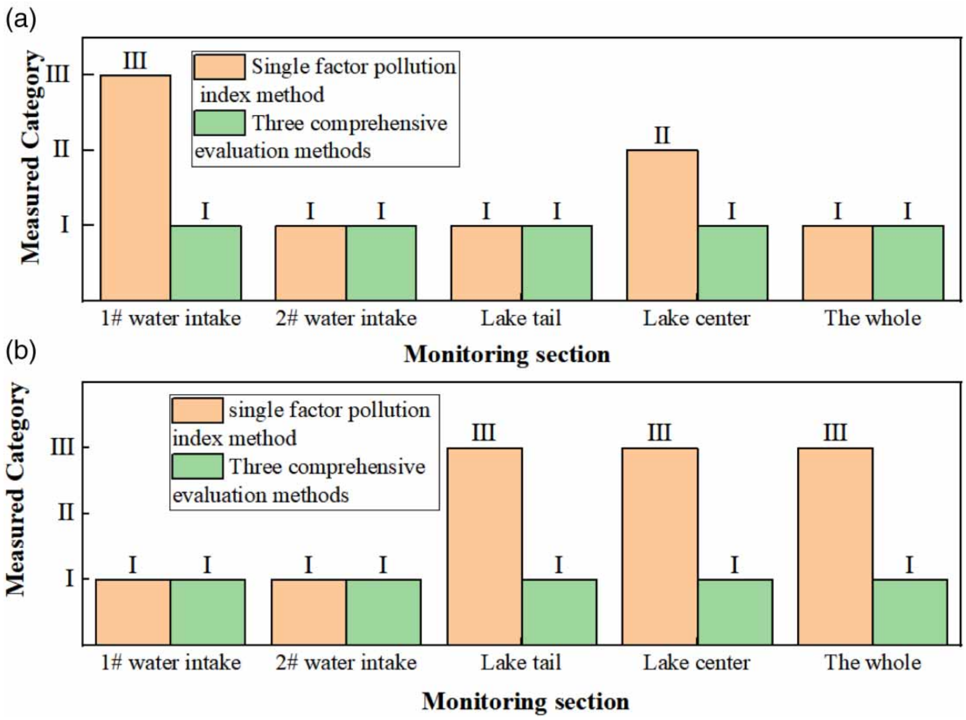


Figure 6 | (a) Comparison of the single factor pollution index method and three comprehensive evaluation methods in 2019. (b) Comparison of the single factor pollution index method and three comprehensive evaluation methods in 2019.

4.2. Comprehensive comparison of evaluation methods

Based on the characteristics of the four evaluation methods, a comprehensive comparative analysis is conducted on the calculation formulas, scientific rationality, and evaluation effects of the four evaluation methods in the water quality evaluation of Sancha Lake. The functions of the four evaluation methods are shown in Supplementary Table S5. The single factor evaluation method is convenient to calculate and intuitive to evaluate. The comprehensive pollution index method is relatively easy to calculate and converts the water quality pollution caused by each indicator into a water quality index, while it can be used for comparison of water quality of similar water bodies, but it does not consider the weight of each indicator. The calculation method of weighted average considers each indicator as the same weight. The Nemerow index method considers the influence of extreme values and average values on water quality, and the evaluation results are more comprehensive. The improved Nemerow index method is more cumbersome to calculate and requires the specific weight of each indicator to be calculated.

5. CONCLUSION

Overall, the water quality of Sancha Lake is good and meets the requirements of water functional zoning. From 2019 to 2021, the monitoring indicators of the monitoring sections met the water quality standards of Class III or above in the 'Environmental Quality Standards for Surface Water'. According to the results of the single factor index evaluation, some monitoring sections of Sancha Lake had water quality of Class II and Class III. Due to regional characteristics, the main pollutants were concentrated in TP, COD_{Cr}, and DO. The comprehensive pollution index method, the Nemerow pollution index method, and the improved Nemerow pollution index method showed consistency in the evaluation results of Sancha Lake's water quality. The evaluation results showed that from 2019 to 2021, all monitoring sections were Class I water quality, indicating no pollution.

Through the comparison of the application of different methods, the advantages and disadvantages of each method have been demonstrated. In actual water quality evaluation management work, when a certain indicator exceeds the standard severely, especially when the indicator with biological toxicity exceeds the standard, it is recommended to use the single factor evaluation method in order to quickly determine the excessive indicator. When the categories of various indicators in a lake are similar, in order to reflect the comprehensive impact of various indicators on water quality, or when the categories of various indicators differ greatly, in order to compare the water quality of lakes belonging to the same category, it is recommended to use the comprehensive pollution index method, the Nemerow pollution index method, and the improved Nemerow pollution index method.

Overall, compared with the other three comprehensive evaluation methods, the single factor evaluation method is more rigorous and conservative, and its results are more pessimistic. The latter considers factors more comprehensively and has a wider range of applications. Therefore, in the future, when evaluating the water quality of lakes, the data should be fully analyzed, and appropriate evaluation methods should be chosen according to the evaluation objectives. The single factor evaluation method can be used in combination with other methods to make the water quality evaluation results more scientifically reasonable.

ACKNOWLEDGEMENT

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DATA AVAILABILITY STATEMENT

All relevant data are included in the paper or its Supplementary Information.

CONFLICT OF INTEREST

The authors declare there is no conflict.

REFERENCES

Chen, H., Gu, J. H. & Li, Z. Y. 2017 Comparison of application of different water quality evaluation methods in urban river water quality assessment. *Journal of Suzhou University of Science and Technology (Engineering and Technology)* **30**(01), 42–46.

Cichoń, M. 2017 Changing values of lake ecosystem services as a result of bacteriological contamination on Lake Trzesiecko and Lake Wielimie, Poland. *Environmental & Socio-economic Studies* (4). doi:10.1515/environ-2017-0024.

Cui, C., Dong, Z. C., Tong, J., Shi, Q. Y., Zhang, T. Y. & Chen, X. 2021 Water quality evaluation and variation analysis of main channels of Hongze Lake. *Jiangsu Water Resources* (09), 27–34 + 49. doi:10.16310/j.cnki.jssl.2021.09.008.

Ding, X. Q. 2010 Application of improved Nemerow index method for evaluation of environmental quality of waterhead area of public drinking water supply. *Sichuan Environment* **29**(02), 47–51. doi:10.14034/j.cnki.schj.2010.02.020.

Du, H., Luan, J. Q. & Liu, X. 2022 Evaluation of water quality in the upper reaches of the Xiaohe River based on grey correlation method. *Yellow River* **44**(S2), 157–158.

Hua, R. X., Zhang, Y. Y., Liu, W. & Yang, Y. H. 2016 Adaptability analysis of multiple evaluation methods in reservoir water quality evaluation. *South-to-North Water Transfers and Water Science & Technology* **14**(06), 183–189. doi:10.13476/j.cnki.nsbdqk.2016.06.031.

Huang, M. Y. 2020 Comparison and analysis of water quality of eighteen streams in Cangshan mountain based on four river water quality evaluation methods. *Journal of Green Science and Technology* (18), 112–114. doi:10.16663/j.cnki.lskj.2020.18.039.

Jia, B. Y., Tang, Y., Zhang, Y. & Zhang, C. 2015 Heavy metal pollution in sediments of Sancha Lake in Sichuan Province and relevant human activities. *Environmental Science & Technology* **38**(03), 168–173 + 194.

Li, X. L., Li, X. D. & Ao, T. Q. 2016 Application of improved Nemerow index method used in water quality assessment of Xichong River. *Yellow River* **38**(08), 65–68.

Li, Y., Zhang, J. J., Zhang, J. Q., Xu, W. L. & Mou, Z. S. 2019 Microbial community structure in the sediments and its relation to environmental factors in eutrophicated Sancha Lake. *International Journal of Environmental Research and Public Health* **16**(11), 1931.

Liu, P. 2012 *Water Quality Evaluation and Pollutant Control Countermeasures of Sanqiao Lake*. Master's Thesis, Sichuan Normal University.

Liu, Y., Ji, Z. Y., Liu, S. J., Ye, C. B., Liu, S. J. & Li, L. 2020 Application and comparison of three methods in water quality evaluation of Plateau Lakes. *Transactions of Oceanology and Limnology* (02), 166–174. doi:10.13984/j.cnki.cn37-1141.2020.02.021.

Liu, Z. Q., B. Z. Pan, X. Han, X., Li, G. & Wang, T. Y. 2022 Water environmental characteristics and water quality assessment of lakes in Tibetan Plateau. *Environmental Science* **43**(11), 5073–5083. doi:10.13227/j.hjkx.202111079.

Lu, W. J. & Zhang, T. 2009 Comparison and analysis of several appraisal methods for river water quality. *Environmental Science and Management* **34**(06), 174–176.

Luo, F., Wu, G. R., Wang, C. & Zhang, L. 2016 Application of Nemerow pollution index method and single factor evaluation method in water quality evaluation. *Environment and Sustainable Development* **41**(05), 87–89. doi:10.19758/j.cnki.issn1673-288x.2016.05.024.

Noori, R., Berndtsson, R., Hosseinzadeh, M., Adamowski, J. F. & Abyaneh, M. R. 2019 A critical review on the application of the National Sanitation Foundation Water Quality Index. *Environmental Pollution* **244**, 575–587.

Peng, S. Y., Zhou, L. C., Bi, J. P., Gan, J. & Liang, J. J. 2020 Application and comparison of different assessment methods for water quality in Liuyang River. *Green Technology* (02), 106–108. doi:10.16663/j.cnki.lskj.2020.02.035.

Saeed, A. & Hashmi, I. 2014 Evaluation of anthropogenic effects on water quality and bacterial diversity in Rawal Lake, Islamabad. *Environmental Monitoring and Assessment* **186**, 2785–2793.

Shen, Z. P. 2019 Water quality evaluation and analysis of Shifosi reservoir based on comprehensive water quality identification index method. *Pearl River* **40**(07), 103–109.

Wang, S. R., Ni, Z. K. & Xi, H. Y. 2016 Management process and strategy of lake eutrophication in China. *Environmental Protection* **44**(18), 15–19. doi:10.14026/j.cnki.0253-9705.2016.18.003.

Xia, W. W., Jiang, R. X. & Wang, J. L. 2022 Water quality evaluation and spatial-temporal characteristics analysis of Hongze Lake based on multivariate statistical analysis. *Environmental Science and Technology* **35**(04), 53–58. doi:10.19824/j.cnki.cn32-1786/x.2022.0046.

Xie, Y., Li, X. Y., Wang, H. L. & Li, W. Z. 2012 Stream pollution analysis and hydrochemical assessment of the upper Luanhe River Basin. *Acta Scientiae Circumstantiae* **32**(03), 645–653. doi:10.13671/j.hjkxxb.2012.03.025.

Yang, L. L., Lu, W. X., Huang, H. & Chu, H. B. 2012 Application of improved Nemerow pollution exponential method and fuzzy comprehensive evaluation method used in water quality assessment. *Water Resources and Power* **30**(06), 41–44.

Yin, X. Y., Yan, G. H., Wang, X., Huang, D. Z. & Li, L. Q. 2023 Applicability of different water quality evaluation methods in river-connected lakes: A case study of Dongting Lake area. *Journal of Environmental Engineering Technology* **13**(03), 1070–1078.

You, R. Y., Ao, T. Q., Zhu, H., Gao, D. Y. & Zhang, X. 2021 Comparative study on water quality evaluation methods of small watersheds. *Sichuan Environment* **40**(02), 73–81. doi:10.14034/j.cnki.schj.2021.02.011.

Zeng, F. L., Yang, G., Wang, P., Jiao, H. Y. & Zhang, T. T. 2021 Temporal and spatial variation of water quality and pollution trend of Huaihe River. *Journal of Hydroecology* **42**(05), 86–94. doi:10.15928/j.1674-3075.202106290209.

Zhang, Y., Feng, X., Wang, S., Jiang, H. B. & Zheng, G. C. 2022 Eutrophication assessment of Hongqipao Reservoir based on back propagation (BP) artificial neural network. *Environmental Ecology* **4**(09), 103–107.

Zhou, Y., Liao, Z. L. & Zhou, C. 2021 The assessment of surface water quality based on support vector machine using decision tree. *Environmental Science and Technology* **34**(05), 57–61 + 66. doi:10.19824/j.cnki.cn32-1786/x.2021.0074.

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