Application of Nemerow Index Method and Integrated Water Quality Index Method in Water Quality Assessment of Zhangze Reservoir

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Abstract:[Objective] Based on the water quality historical data from the Zhangze Reservoir from the last five years, the water quality was assessed by the integrated water quality identification index method and the Nemerow pollution index method. The results of different evaluation methods were analyzed and compared and the characteristics of each method were identified.[Methods] The suitability of the water quality assessment methods were compared and analyzed, based on these results.[Results] the water quality tended to decrease over time with 2016 being the year with the worst water quality. The sections with the worst water quality were the southern and northern sections.[Conclusion] The results produced by the traditional Nemerow index method fluctuated greatly in each section of water quality monitoring and therefore could not effectively reveal the trend of water quality at each section. The combination of qualitative and quantitative measures of the comprehensive pollution index identification method meant it could evaluate the degree of water pollution as well as determine that the river water was black and odorous. However, the evaluation results showed that the water pollution was relatively low.The results from the improved Nemerow index evaluation were better as the single indicators and evaluation results are in strong agreement; therefore the method is able to objectively reflect the water quality of each water quality monitoring section and is more suitable for the water quality evaluation of the reservoir.

1. Introduction

China's river water quality assessments utilize many kinds of research methods including gray correlation method[1], fuzzy comprehensive evaluation method[2], artificial neural network evaluation method[3], single factor evaluation method[4], water quality identification index method[5], principal component analysis[6~7] and so on. Both within China and internationally, a series of important studies have been conducted on the selection and evaluation methods of water quality evaluation indexes. Kou et al. [8] amended the problem of missing water quality levels in the calculation and solved the problem of numerical limitation in water quality evaluation which better reflected the real situation. Yang Leilei

[9] carried out a water quality evaluation on the water quality monitoring data of five major monitoring sections in Huadian during the dry season of 2010. The results showed that the improved Nemerow index method is more suitable for grasping the degree of water pollution.

Based on the water quality data from the three monitoring sections of Zhangze Reservoir in Changzhi City from 2012 to 2016 the water quality of the reservoir was assessed using the integrated water quality identification index method and the Nemerow pollution index method, which was improved by considering six weighted factors. Analysis and evaluation of the advantages and disadvantages of these methods were used to analyze the applicability of these methods for the Zhangze Reservoir.

2. Theory and method

2.1 Integrated water quality labeling index method
(1) Single factor water quality identification index method

$$P_i = X_1.X_2X_3 \tag{1}$$

1) determination of $X_1.X_2$

Non dissolved oxygen index and Dissolved oxygen index：

$$X_1.X_2 = a + \frac{\text{measured values - Lower limit values of } X_1}{\text{Upper limit values of } X_1 \text{ - Lower limit values of } X_1} \tag{2}$$

$$X_1.X_2 = a + \frac{\text{Upper limit values of } X_1 \text{ - measured value}}{\text{Upper limit values of } X_1 \text{ - Lower limit values of } X_1} \tag{3}$$

Type: a is determined by monitoring data and standards, a takes 1,2,3,4,5.
2) determination of X_3

$$X_3 = X_1 - f_i \tag{4}$$

Type: f_1 is the water environment functional area category.
(2) comprehensive water quality identification index method

$$I_{wq} = (\Sigma P_i/n)X_3X_4 \tag{5}$$

2.2 Traditional Nemerow pollution index method

$$F_i = C_i / S_{ij} \qquad i = 1,2,3......n; \quad j = 1,2,3......m \tag{6}$$

$$P_{\text{traditional}} = \sqrt{(F^2_{\max} + F^2_{\text{average}})/2} \tag{7}$$

Type: C_i — Measured concentration of class I evaluation factors;

S_{ij} — Class J standard concentration of class I evaluation factors;

2.3 The improved Nemerow index method

$$P_{\text{Improve}} = \sqrt{(F^2_{\max} + F'^2)/2} \tag{8}$$

Type: F' is the F value corresponding to the most heavily weighted pollution factor.
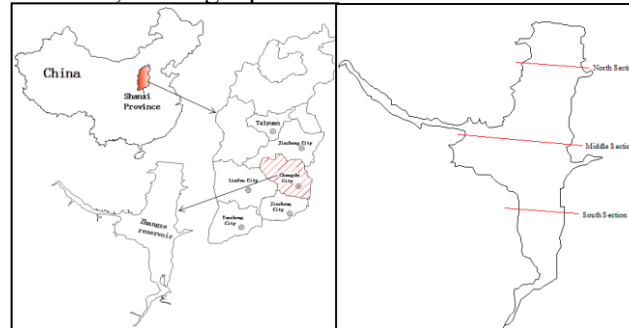
3. The water quality assessment of Zhangze Reservoir

3.1 Research areas and data
Zhangze Reservoir is located on the main source of the Zhuozhang River north of Changzhi City, Shanxi Province. Its geographical location is 113 ° 08'E and 36 ° 26'N, with an average elevation of 1,000m and a total storage capacity of $9.127 \times 10^8 m^3$. The main dam above the dam site is 72.3km long with a controlled drainage area of 3176km². [10]

The research data was obtained from the three water quality monitoring sections of Zhangze Reservoir in the northern, central, and southern areas of the reservoir. The data was measured quarterly

from 2012 to 2016.The water quality monitoring section layout of the reservoir area is shown in Fig.1. Ammonia nitrogen, COD, DO, TP, BOD$_5$ and TN were selected according to the "Surface Water Environmental Quality Standard", totaling 6 pollution indicators.

(a) Reservoir location map   (b) Reservoir sampling section layout

Figure 1. Zhangze reservoir location and sampling section layout

3.2 Evaluation Results

Table 1. different methods of water quality evaluation results

Time	Section	Comprehensive pollution index method		Ptradition		Pimprove	
First quarter of 2012	North Section	4.131	IV	2.1659	IV	1.3160	IV
	Middle Section	4.041	IV	2.2046	IV	1.3484	IV
	South Section	3.940	III	2.2068	IV	1.3517	IV
Second quarter of 2012	North Section	3.540	III	1.8890	IV	1.1371	IV
	Middle Section	3.340	III	1.8478	IV	1.1162	IV
	South Section	3.640	III	2.1073	IV	1.2948	IV
Third quarter of 2012	North Section	4.941	IV	4.2855	V	2.8000	IV
	Middle Section	4.031	IV	2.8134	IV	1.7800	IV
	South Section	4.131	IV	2.6840	IV	1.6903	IV
Fourth quarter of 2012	North Section	4.241	IV	3.0848	IV	1.9700	IV
	Middle Section	3.830	III	2.6041	IV	1.6403	IV
	South Section	3.830	III	2.3072	IV	1.4336	IV
First quarter of 2013	North Section	4.031	IV	2.2341	IV	1.3682	IV
	Middle Section	3.730	III	2.1710	IV	1.3381	IV
	South Section	3.730	III	2.0942	IV	1.2859	IV
Second quarter of 2013	North Section	3.730	III	2.1368	IV	1.3155	IV
	Middle Section	3.630	III	2.1119	IV	1.3063	IV
	South Section	3.730	III	2.0624	IV	1.2674	IV
Third quarter of 2013	North Section	4.131	IV	3.9709	V	2.6180	IV
	Middle Section	4.231	IV	3.9979	V	2.6342	IV
	South Section	4.431	IV	4.2344	V	2.7939	IV
Fourth quarter of 2013	North Section	4.131	IV	3.8876	V	2.5594	IV
	Middle Section	4.231	IV	3.7215	V	2.4413	IV
	South Section	4.231	IV	3.7532	V	2.4562	IV
First quarter of 2014	North Section	3.830	III	3.1726	IV	2.0594	IV
	Middle Section	3.930	III	3.3422	IV	2.1772	IV
	South Section	3.730	III	2.9733	IV	1.9176	IV

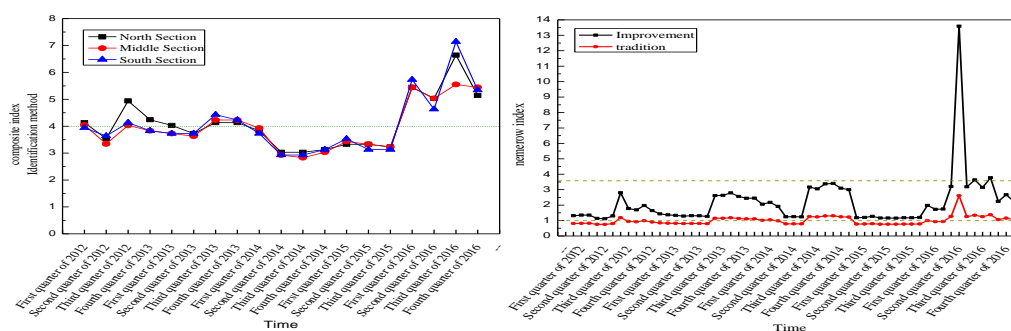| Time	Section						
Second quarter of 2014	North Section	3.030	III	1.9803	IV	1.2415	IV
	Middle Section	2.930	II	1.9864	IV	1.2481	IV
	South Section	2.930	II	1.9676	IV	1.2348	IV
Third quarter of 2014	North Section	3.030	III	4.7138	V	3.1700	IV
	Middle Section	2.830	II	4.5402	V	3.0500	IV
	South Section	2.930	II	4.9960	V	3.3700	IV
Fourth quarter of 2014	North Section	3.130	III	5.0451	V	3.4000	IV
	Middle Section	3.030	III	4.6175	V	3.1000	IV
	South Section	3.130	III	4.4772	V	3.0000	IV
First quarter of 2015	North Section	3.330	III	1.9105	IV	1.1823	IV
	Middle Section	3.430	III	1.9542	IV	1.2017	IV
	South Section	3.530	III	2.0639	IV	1.2712	IV
Second quarter of 2015	North Section	3.330	III	1.8812	IV	1.1612	IV
	Middle Section	3.330	III	1.8798	IV	1.1612	IV
	South Section	3.130	III	1.8629	IV	1.1542	IV
Third quarter of 2015	North Section	3.230	III	1.8942	IV	1.1753	IV
	Middle Section	3.230	III	1.8924	IV	1.1753	IV
	South Section	3.130	III	1.9234	IV	1.2033	IV
First quarter of 2016	North Section	5.442	V	3.1926	IV	1.9790	IV
	Middle Section	5.442	V	2.8466	IV	1.7324	IV
	South Section	5.732	V	2.8612	IV	1.7471	IV
Second quarter of 2016	North Section	5.032	V	4.8355	V	3.2100	IV
	Middle Section	5.032	V	19.5199	V	13.5900	V
	South Section	4.631	IV	4.7841	V	3.1800	IV
Third quarter of 2016	North Section	6.643	Worse than Grade V but not stinky	5.5086	V	3.6306	V
	Middle Section	5.552	V	4.7773	V	3.1436	IV
	South Section	7.144	Inferior V class and black smelly	5.7239	V	3.7761	V
Fourth quarter of 2016	North Section	5.142	V	3.5197	V	2.2441	IV
	Middle Section	5.442	V	4.1449	V	2.6754	IV
	South Section	5.342	V	3.5210	V	2.2361	IV

Figure2. Three kinds of pollution index evaluation results of the change trend

3.3 comparative analysis

(1) Integrated water quality index method：The water quality standards from 2012 to 2015 were all around Class III. The changes in the water quality in each section were relatively stable during this period, essentially meeting the requirements. However, the water quality began deteriorating with 2016 being the year with the poorest water quality. The results of the integrated index method showed the water pollution level of all three section reaches Class V in 2016; especially in the third and fourth quarters when the water pollution significantly exceeded the standard requirements.

(2) The results of the traditional Nemerow pollution index evaluation：According to Table 1,it can be seen that the water quality standards in class IV and above. The degree of water pollution in the third and fourth quarter of every year was more severe than in the first two quarters and reached class V in 2016. The main reason for this is believed to be a result of the temperature decrease and the change of biological activity around the reservoir. It can be concluded that the degree of water pollution is gradually aggravated from 2012 to 2016. Especially in 2016, when the trend of water quality deterioration is most severe, resulting in the water failing to meet the requirements of human drinking standards and the imminent need for water quality control.

(3) Improved Nemero Pollution Index Evaluation Results：The results showed that the pollution levels of all three monitoring sections exceeded Grade III water quality standards during the five years which were monitored. of which, the second and third quarter of 2016 in the North and South sections were all evaluated as Class V, the most serious pollution classification. The remaining sections were rated as a Class IV. Overall, water quality changes were stable from 2012 to 2015 but deteriorated dramatically in 2016 to unsuitable levels indicating water quality control should be implemented without delay.

4. Conclusion

(1) The evaluation results showed：①the results of the traditional Nemerow index were good but the variation of the results were too large to show the degree of water pollution in the monitoring section so the result is generally unreliable. ②The integrated pollution index can not only determine the water quality classification but also evaluate the degree of pollution and judge whether the water is black or odorous. The combination of qualitative and quantitative results made it more comprehensive, but the evaluation results showed that the degree of water pollution was relatively low. The difference between the evaluation results and the single index was larger. ③The improved Nemerow index evaluation results were better, as they agreed well with the single index evaluation results which objectively reflected the water quality of each water quality monitoring section. Therefore, the improved Nemerow index was more suitable for the water quality evaluation of the reservoir.

(2) As can be seen from the above assessment, the pollution was more serious in the third and fourth quarter every year. The possible reasons being :①The gradual falling temperature, weak biological activity and the slower absorption and decomposition of pollutants. ② The low temperatures, that resulted in partial freezing of the lake, which are not conducive to the role of hydrodynamics. ③The relatively lower throughput of the reservoir during the dry season. Overall, the water quality is relatively stable from 2012 to 2015, however in 2016 the water quality began deteriorating more seriously.

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