Nature Environment and Pollution Technology
An International Quarterly Scientific Journal
p-ISSN: 0972-6268
(Print copies up to 2016)
e-ISSN: 2395-3454
Vol. 21 | No. 2 | pp. 711-719 | 2022

Original Research Paper
https://doi.org/10.46488/NEPT.2022.v21i02.032
Open Access Journal

Water Quality Evaluation and Spatiotemporal Variation Characteristics of Wenyu River Based on Comprehensive Water Quality Identification Index Method

Wang Keke, Men Baohui† and Xing Yanling
School of Water Resources and Hydropower Engineering, North China Electric Power University, Beijing 102206, China
†Corresponding author: Men Baohui; menbh@ncepu.edu.cn

Nat. Env. & Poll. Tech.
Website: www.neptjournal.com

Received: 23-04-2021
Revised: 10-07-2021
Accepted: 14-07-2021

Key Words:
Water quality evaluation
Spatiotemporal variation
Wenyu river
Water quality indicators

ABSTRACT

In recent years, the water environment management of the Wenyu River has yielded positive outcomes. In comparison to earlier, the general water quality has substantially improved. However, some areas' water quality has not improved as a result of the overall trend of improvement, which has implications for the surrounding areas and the entire water environment. To further explore the water environmental quality of specific river sections, this paper adopts the five monitoring sections of Shahe Gate, Mafang, Lutuan Gate, Xinbao Gate, and the additional sewage outlet in 2019, and the three main water quality indicators of COD, DO, and NH_3-N. The water quality of the Wenyu River was evaluated using the comprehensive water quality identification index method, and the characteristics of its temporal and spatial changes were studied using correlation analysis and spatial clustering. The results have shown that the Wenyu River is generally Grade V water during the flood season, and is inferior to Grade V water during the non-flood season. All indicators have a regular time and space distribution and are highly influenced by environmental and human factors. Overall, the water quality of the Wenyu River may essentially reach the water environment function zoning target value. Improvements to the river portions below the Xinbao sluice, as well as the use of rainwater resources, must be prioritized.

INTRODUCTION

Wenyu River is located in the northeast of Beijing, which has many springs along the coast and rich geothermal resources (Cai et al. 2014) Many rivers converge on this river and eventually flow into the ocean. It is an important river in Beijing. Therefore, studying the water quality and change characteristics of the Wenyu River is of great significance to the overall economic planning and urban construction.

Water quality evaluation is of great significance to the formulation of water governance and water policy in a certain area. Appropriate water quality evaluation methods can better reflect the water quality status and pollution characteristics of a certain area. Currently, there are many ways for assessing water quality. The grey evaluation method, fuzzy comprehensive analysis method, matter element analysis method, and others are the primary methodologies (Wang 2008). The advantages and disadvantages of these methods are often compared to see if they are accurate in a certain area. In the water quality study of the Ikare community, Oladipo Johnson et al. (2021) compared and examined the findings of fuzzy logic and water quality index methodologies. In equal consideration of measured values and surface water quality, fuzzy logic outperforms the water quality index, according to the evaluation results. Both models, however, can differentiate rivers based on the quality of their water. Ning et al. (2020) used five different methods to evaluate the water quality of the Three Gorges section of the Huangshi section of the Yangtze River, including the single factor evaluation method, the comprehensive water quality label index method, and the single factor water quality label index method. The complete water quality label index method has the best effect and can fundamentally determine numerous elements of water quality, according to the findings. Other methods have their own advantages and limitations. The water quality index method is widely used in water quality evaluation and its evaluation results have good reliability. Howladar et al. (2021), for example, observed pollution of related water quality in the Surma River area of Bangladesh. According to the findings, the river's middle sections are heavily contaminated. The related limitations for BOD, COD, TSS, CO_2, and turbidity are all exceeded. Relevant proposals are made in light of the existing water pollution problem. Suriadikusumah et al. (2020) investigated the physical, chemical, and microbiological parameters of the Cipeusing River using the pollution index method. According to the findings, the river was moderately polluted in 2016 and highly polluted in 2017. The primary cause is pollution caused by humans. So there should be technical improvements and perfections in response to the problems in this area. Nong et al. (2020) investigated the seasonal and regional characteristics of water quality in the South-to-North Water Diversion Project by monitoring 16 water quality parameters and using 5 key factors to create a minimum water quality index model and evaluate the water quality. The findings show that the water quality remained stable during the research phase and that it was "great." The research results demonstrated the reliability and accuracy of the water quality index approach. As a result, the water quality index approach has a high reference value in today's water quality assessment, and its application possibilities are vast. To analyze the water quality of the Wenyu River, this article uses the comprehensive water quality index approach, which can do both quantitative and qualitative water quality evaluations. In particular, it is feasible to assess the degree of pollution in water of worse quality than Grade V (Xu 2005a, Liang et al. 2013). In this study, we also exemplify the current positive state of water quality management. Although the water quality, in general, has improved, the water quality in some places of the Wenyu River remains unfavorable. Five monitoring sections of Shahe Gate, Mafang, Lutuan Gate, Xinbao Gate, and the additional sewage outflow were chosen as research sample stations to better investigate the water quality in various places. To study its temporal and spatial distribution characteristics through the final evaluation results, we can further understand the water quality distribution in the research section and the current water pollution problems.

MATERIALS AND METHODS

Overview of the Study Area

With a total length of 47.5 km, the Wenyu River is an older developed river in Beijing's history. The confluence of three tributaries of the Dongsha River, Beisha River, and Nansha River forms the upper parts of the river. The ecological management of the Wenyu River has yielded preliminary results in recent years. The well-known "six demonstrations" (Beijing Municipal Bureau of Ecological Environment n.d.) in the water purification demonstration area of the constructed wetland in Wenyu River. The specific locations are shown in Fig. 1.

Monitoring Data

Field measurements and laboratory water sample processing are used to obtain monitoring data. The data in this article is based on observations from five parts over the course of 2019. Water samples are taken once a month from each of them. DO, COD, NH3-N, and other water quality indicators are commonly used. In 2019, the experimental data is based on the average monthly monitoring data from five monitoring areas. Fig. 2(a)(b) shows the monitoring data for each indicator:

Research Methods

Comprehensive Water Quality Labeling Index Method

The comprehensive water quality labeling index method (Gu et al. 2016) is a method for calculating complete water quality information based on the single-factor water quality labeling index approach (Xu 2005b). The following is the structure of the complete water quality labeling index, which is made up of integer digits with three or four decimal places (Xu 2005a, 2005b):

$$I_{wq} = X_1.X_2X_3X_4 \qquad \dots(1)$$

where I_{wq} is the comprehensive water quality labeling

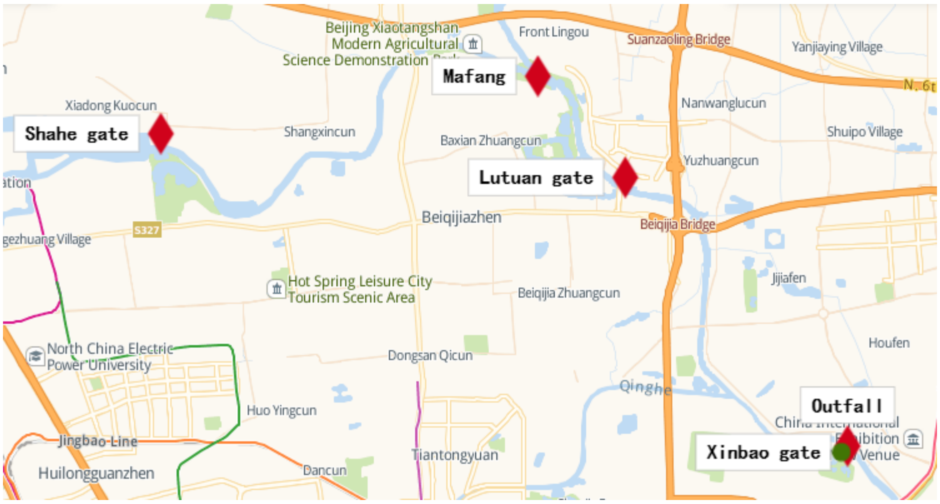

Fig. 1: Sampling points of each monitoring section.

index, $X_1.X_2$ is the average value of the single-factor water quality labeling index of all measured values; X_3 is the number of single indicators in the complete water quality evaluation that are inferior to the water environment functional zone target.; X_4 is the result of a comparison between the comprehensive water quality category and the overall water environment function zone's target value. X_4 can be one or two significant digits depending on the degree of pollution in the overall water quality.

$$X_1.X_2 = \frac{1}{n}\sum_{1}^{n} P_i \qquad \ldots(2)$$

The n is the number of water quality indicators, and P_i is the single-factor water quality indicator index of the i-th water quality indicator.

Coefficient of Variation Weighting Method

In the classic comprehensive water quality labeling index, the average value of each single-factor water quality labeling index is directly employed as the end result. It cannot emphasize the objective influence of excessive concentration and the severity of factor changes on water quality, nor can it emphasize the subjective impact of subjective factors, which has some limits (Sun et al. 2019). Cheng et al. (2019), in their study of many weighting methods, concluded that the results of weighting methods based on the coefficient of variation are reasonable and reliable, and can objectively reflect the relative relevance of each assessment index. As a result, this study uses this weighting method to determine the importance of each indicator. The following is the formula for calculating it:

$$V_i = \frac{\delta_i}{\sum_{1}^{n} \delta_i} \qquad \ldots(3)$$

$\overline{C}_i$ where V_i is the weight of the i-th index; δ_i is the coefficient of variation of the i-th index; $\delta_i = \frac{S}{\overline{C}_i}$, S_i is the mean square error of the i-th index; is the average mass concentration of the i-th index; n is the number of evaluation indexes.

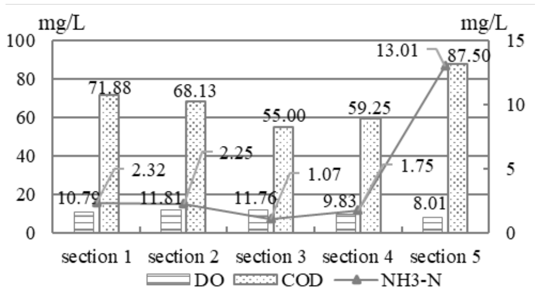

Fig. 2(a) Monitoring data of each the section in the flood season.

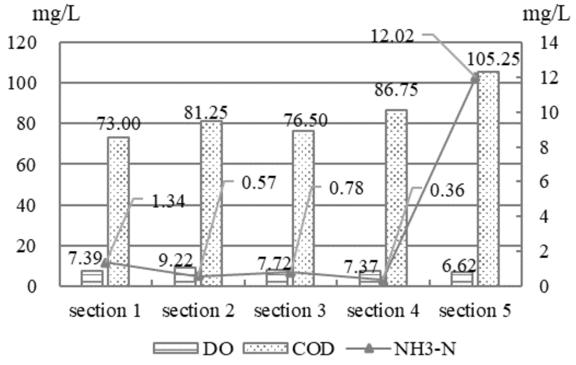

Fig. 2(b) Monitoring data of each section during non-flood season.
Note: June to September is the flood season

RESULTS AND DISCUSSION

The Evaluation Results

The single-factor water quality labeling index method was used to process the monitoring data, and the results are shown in Table 1 below.

Using the coefficient of variation weighting method to calculate the weight of each item, the results are shown in Table 2.

According to the weight coefficient and the data of the single-factor water quality labeling index method, the overall evaluation of the water body is carried out, and the results are shown in Table 3.

Seen from the evaluation results, three indicators' impact on water pollution sorted for COD> NH_3-N> DO, the overall water quality during the flood season is Grade V water, and the non-flood season is inferior to Grade V water. This result is similar to that of Cai et al. (2019). The improved evaluation results are more differentiated than before. The water quality is better during the flood season, and worse during the non-flood season. This is because the traditional method does not consider the weight of each evaluation factor, but the coefficient of variation has considered the differences between the indicators, which can objectively reflect the relative importance of each indicator (Cheng et al. 2019), making the evaluation results more accurate. The phenomenon that water quality in the flood season is better than the water quality in the non-flood season is reflected in the related studies of Li & Wang (2007) and Yang et al. (2011).

The main reason is that at the start of the flood season (June), surface runoff brings a large amount of land-sourced pollutants accumulated during the dry season, resulting in a higher concentration of surface water; in the wet season, the pollutants are diluted under the wash of rain, and the concentration decreases; in late August of the flood season, with the gradual decrease of rainfall, the concentration of some pollutants has rebounded, but compared to the beginning of the flood season, the concentration of some pollutants has decreased (Yang et al. 2011).

Time-Varying Characteristics

The law of time change: We use the clustering method to classify each month's water quality, SPSS to analyze the data, and the Euclidean distance to quantify the distance between the indicators (Fovell & Fovell 1993). The final clustering result is shown in Fig. 3.

According to the clustering results, 12 months can be divided into 3 categories, among which January, May, July, August, and November are one category, February, March, April, and December are one category, and June, September, and October are one category.

Variation law of each index: To further analyze the influence of relevant indicators on the time distribution law, the trend chart of DO, COD, and NH_3-N over time is drawn as shown in Fig. 4.

The DO concentration gradually decreases from January to July, increases in August and September, and decreases in October; the COD concentration fluctuates within a certain range from January to May, with an obvious peak in June and September and a significant decrease in August and November; and the NH3-N concentration is lower from June to October, and higher from January to March, and fluctuates within a certain range at a certain time.

We use the Pearson coefficient to analyze the correlation between COD, DO and NH_3-N with water temperature and

Table 1: Calculation result of water quality index P_i for each section.

Monitoring section	Section name	Water season	Water function zoning target value	DO [$mg.L^{-1}$]	COD_{cr} [$mg.L^{-1}$]	NH_3-N [$mg.L^{-1}$]
Section 1	Shahe gate	flood season	IV	1.10	6.82	4.70
		Non-flood season		1.70	9.25	6.62
Section 2	Mafang	flood season	IV	1.40	10.16	3.10
		Non-flood season		1.90	8.84	6.52
Section 3	Lutuan gate	flood season	IV	1.00	9.75	3.60
		Non-flood season		1.90	7.53	4.10
Section 4	Xinbao gate	flood season	V	1.10	10.75	2.60
		Non-flood season		1.50	7.92	2.50
Section 5	Outfall	flood season	V	1.60	7.63	26.11
		Non-flood season		1.10	10.85	28.13

Note: data of Water function zoning target values are from the Beijing Municipal Bureau of Ecological Environment (n.d.).

Table 2: Weight coefficients of each indicator.

Monitoring section	Water season	Weight of each indicator		
		DO	COD	NH_3-N
Section 1	flood season	0.071	0.025	0.067
	Non-flood season	0.088	0.047	0.070
Section 2	flood season	0.034	0.019	0.169
	Non-flood season	0.048	0.041	0.077
Section 3	flood season	0.034	0.020	0.074
	Non-flood season	0.040	0.049	0.097
Section 4	flood season	0.026	0.025	0.307
	Non-flood season	0.035	0.065	0.114
Section 5	flood season	0.032	0.030	0.069
	Non-flood season	0.047	0.065	0.116

PH, and make a scatter plot for the two items with strong correlation. The correlation analysis results are shown in the following Tables 4, 5, and 6 respectively, and the scatter plot is shown in Fig. 5, 6,7(a) (b) respectively.

From the correlation analysis results and the scatter plot, it can be seen that the DO concentration and PH are basically in a significant positive correlation throughout the year, and DO have little correlation with temperature. The scatter plot is in good agreement with the data analysis results. The explanation for its distribution law, according to the law of DO over time and the results of the correlation study, is mostly related to the algae in the water. In a mildly alkaline environment, suspended plants such as algae are densely spread in the water, and diatom species are very active (Hulyal & Kaliwa 2009). The water quality of the Wenyu River was slightly alkaline, but as the PH grew, phytoplankton photosynthesis increased, and DO concentration increased, the two had a strong relationship, which was consistent with Zhu et al. (2020). From January to March, the temperature is more suitable as well as the acidity and alkalinity of the water are more suitable. Large aquatic organisms have strong photosynthesis, so DO concentration is high. In August and September, the rainfall intensity increases, and the aquatic environment has high turbulence, increasing atmospheric replenishment in the water, as well as an increase in DO.

The COD concentration has little correlation with PH and temperature, so there is no need to draw a scatter diagram to verify its correlation. The distribution of COD does not match the time change of the flood season and the non-flood season, so precipitation is not a factor affecting COD. The source of biogenic organic matter of COD is mainly biological metabolism and organic matter produced by the decomposition of corpses (Pan et al. 2020). Because phytoplankton photosynthesis is strong in the summer, producing more oxygen, the COD content in the water body is comparatively low; but, because photosynthesis is weak in the fall and winter, the COD concentration rises to some amount. In July and August, however, the concentration reduces considerably, whereas, in June and September, it climbs. Other sources of organic input, such as sewage discharge and the application of herbicides and fertilizers, could cause COD concentrations to fluctuate to some extent.

NH_3-N is negatively correlated with PH in flood seasons, has little correlation in non-flood seasons, and has little correlation with temperature. The results of the image and the table are consistent. For NH_3-N, microorganisms in water can treat ammonia nitrogen in water through nitrification reaction, and this decomposition conversion process is more efficient in a slightly alkaline environment (Wang 2021) and nitrifying bacteria have the highest activity at pH 7~8 (Mogeng 1997). The water quality is weakly alkaline, the PH rises, the nitrification reaction rate is faster, and the NH_3-N concentration in the water then decreases, so the NH_3-N has a good negative correlation with PH. The suitable temperature for the nitrification reaction of nitrifying bacteria is 20~30°, the reaction rate decreases below 15°, and basically stops at 5°. According to the measured data, the temperature in Wenyu River from January to April is basically around 0.2~17.6, so the temperature is relatively low, and the microbial reproduction and the reaction rate are reduced, so ammonia

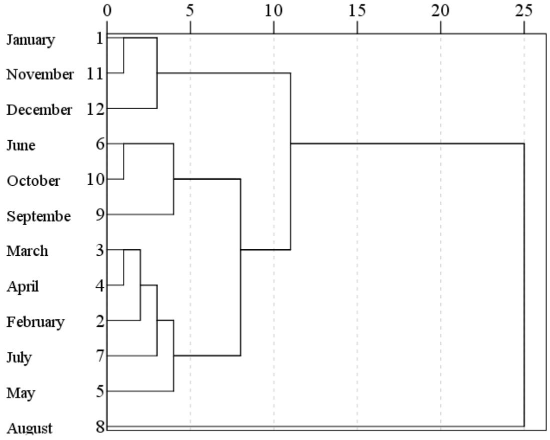

Fig. 3: Time clustering results using average join.

Table 3: Comparison results before and after method improvement.

	After improvement	Before improvement
Flood season	5.060	6.161
Non-flood season	7.782	6.781

Table 4: Correlation between DO and environmental factors

DO	PH	Temperature
Flood season	0.645	0.496
Non-flood season	0.581	-0.689

Table 5: Correlation between COD and environmental factors.

COD	PH	Temperature
Flood season	0.029	-0.382
Non-flood season	0.033	0.086

Table 6: Correlation between NH_3-N and environmental factors.

NH_3-N	PH	Temperature
Flood season	-0.404	-0.235
Non-flood season	-0.269	0.084

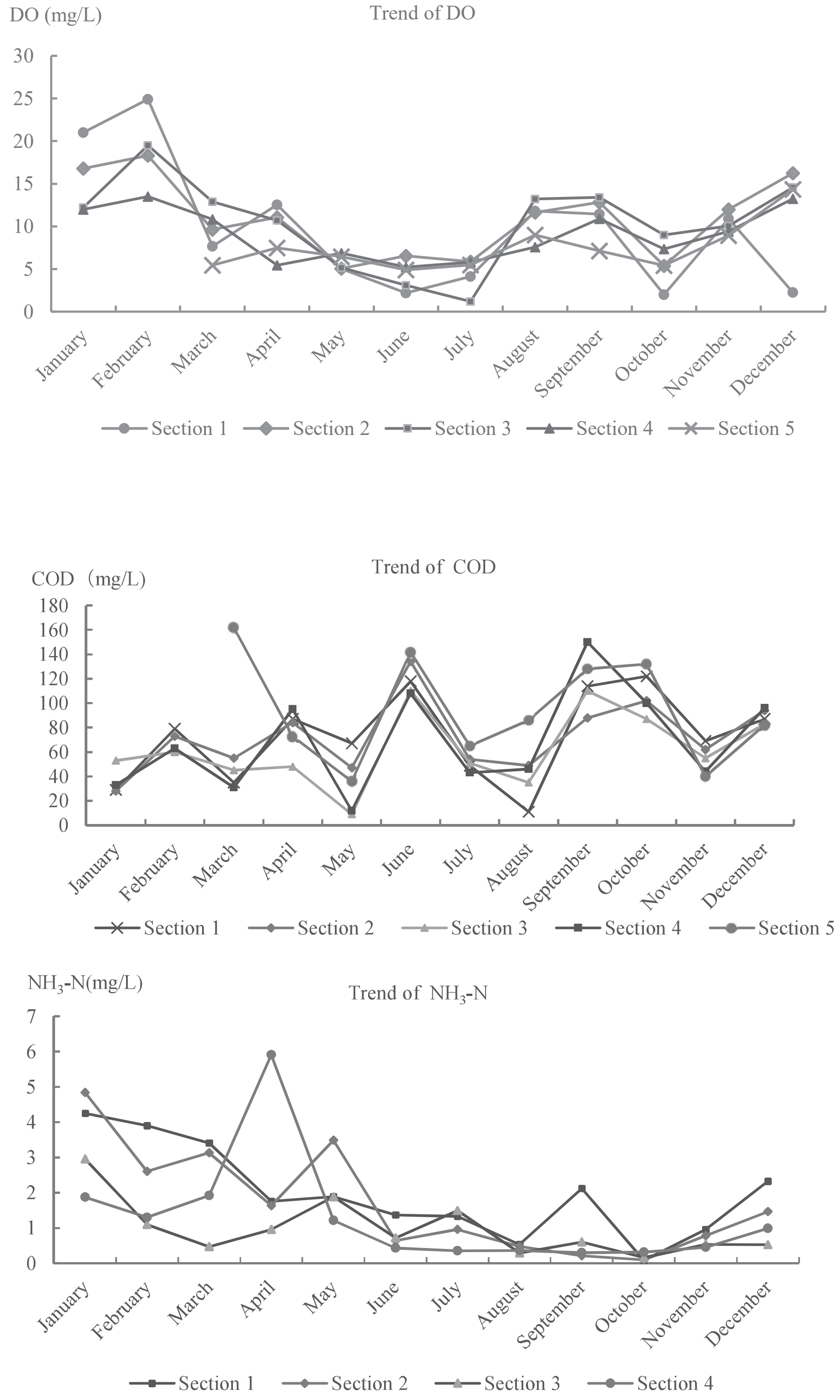

Fig. 4: Trends of water quality indicators in 2019.

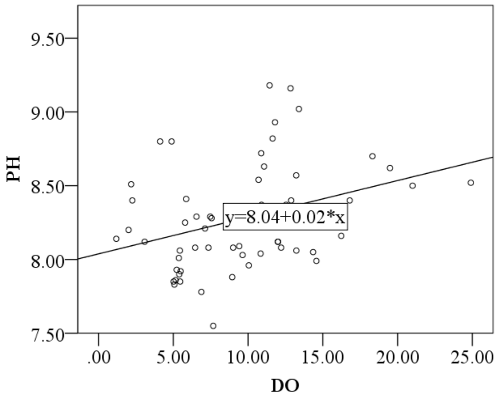

Fig. 5: Scatter plot of DO and pH.

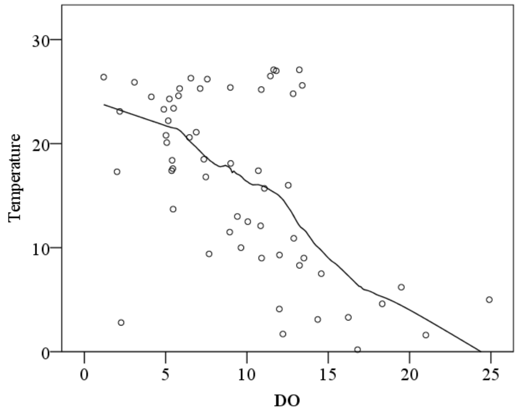

Fig. 6: Scatter plot of DO and temperature.

nitrogen concentration is high from May to September, the temperature is in the range of 20.1~127.1, which is the ideal temperature for the nitrification reaction. As a result, the reaction rate is fast and the NH3-N concentration is low. From October to December, the temperature range shifted from 2.8~118.5, the temperature dropped, the reaction rate dropped, and the concentration rose again.

Based on the above analysis, the water body generally presents a seasonal change pattern, with low pollution indicators during the flood season from June to September, and relatively high pollution indicators in other months during the non-flood season, which is related to the impact of human factors such as agricultural non-point source pollution.

Spatial Distribution Characteristics

Use spatial clustering method to cluster analysis of five sections, use SPSS to process the data, and evaluate the water quality of each section separately. The final classification results are shown in Fig. 8, and the results of water quality evaluation are shown in Table 7.

The five sections can be separated into two categories, as shown in the diagram. Sections 1, 2, 3, and 4 are all part of the same category, whereas section 5 is a single category with water quality that is significantly lower than category V. The spatial clustering and water quality evaluation results were extremely consistent.

Many more effective treatment experiments and related studies have been conducted for the Wenyu River's water quality management. To analyze the Longdao River of the Wenyu River, Zhu et al. (2021) used bypass offline river purifier technology and system. The "pond-wetland system" and the Longdao River pseudo-natural river course project are built without altering the river course's original state, and the wetland and river course's purification functions are used to fulfill the goal of water purification. This method has achieved the goal of reducing COD by 30%, ammonia nitrogen by 20%, and total phosphorus by 15%. It is a quasi-natural process with low cost and good treatment effect. In addition, sewage treatment measures also include the United

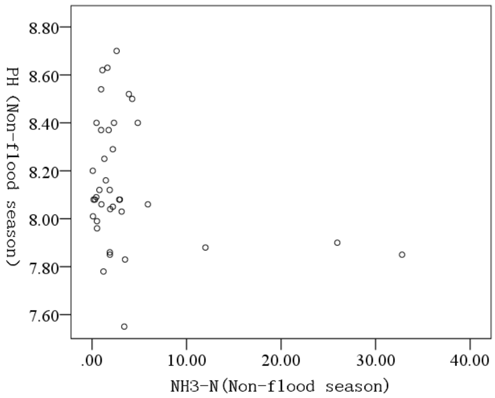

Fig. 7(a): Scatter plot of NH$_3$-N and PH during non-flood season.

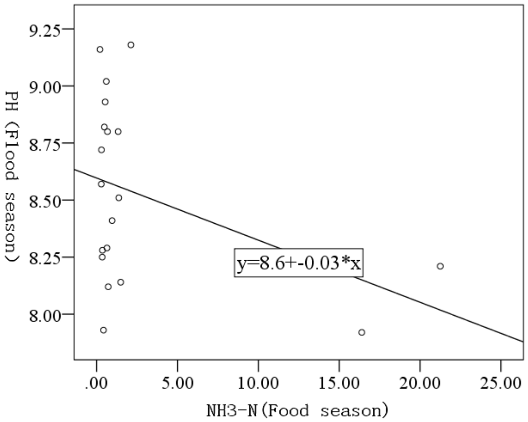

Fig. 7(b): Scatter plot of NH$_3$-N and PH during flood season.

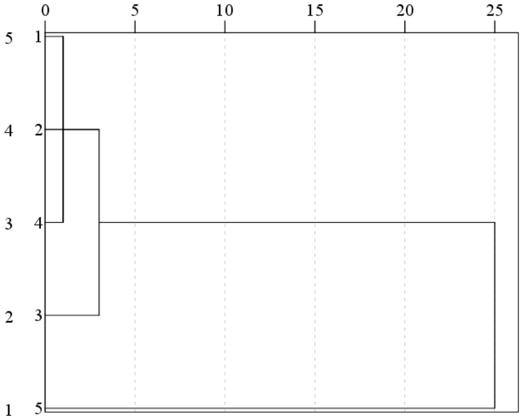

Fig. 8: Spatial clustering analysis results Using average join.

States Micro-Bac bioremediation technology, biological channel sewage treatment technology, and other processes (Wang et al. 2010). Although these sewage treatment processes have achieved certain results, the experimental section 5 is still inferior to Class V water, and the concentration of pollutants is high. This is related to the high overall sewage discharge volume, large base, and the discharge of sewage from the sewage outlet of the river (Zhong et al. 2011). The impact of human factors on the water environment cannot be ignored. We should further improve the sewage treatment process, strengthen the monitoring and treatment of discharged sewage, pay attention to water quality issues, and fundamentally improve the water environment.

CONCLUSIONS

a. Using the comprehensive water quality labeling index method, it is determined that the Wenyu River is rated as Class V water during the flood season, and is inferior to Class V during the non-flood season. The contribution of the three water quality indicators to water pollution is COD>NH_3-N>-DO, and the water quality can reach the target value of the water environment function zone in most areas. But there are still some areas with poor water quality. All in all, water quality urgently needs to be improved.

b. Using clustering method and correlation analysis to analyze the water quality of each index and each month, 12 months can be divided into 3 categories. January, May, July, August, and November are one category; Months, March, April, and December are one category, and June, September, and October are one category. According to the time variation of each index, it can be known that the main reason for the time difference in water quality is related to pH and temperature. Phytoplankton photosynthesis and the decomposition of nitrifying bacteria are affected by these two environmental factors. Changes in pH and temperature caused different reaction rates, which ultimately resulted in better water quality in June-September than in other months.

Table 7: Water quality evaluation results of each section.

Monitoring section	Water function zoning target value	Water Quality Index
Section 1	IV	4.320
Section 2	IV	4.720
Section 3	IV	3.910
Section 4	V	4.710
Section 5	V	8.223

c. For cluster analysis of the 5 monitoring sections, use the spatial clustering approach, and for water quality evaluation, use the comprehensive water quality labeling index method. The five portions can be categorized into two groups. Sections 1, 2, 3, and 4 belong to the same category, whereas section 5 belongs to a different category, and the water quality evaluation results of sections 1-4 all meet the water environment function's target value. Section 5's water quality is low, and its overall performance is inferior to category V. The outcomes of these two strategies were remarkably consistent. Human factors have a significant impact on Section 5's water quality. Despite the existence of modern sewage treatment infrastructure, results are still lacking. To address the problem of water contamination, it is required to enhance the process and begin at the source.

ACKNOWLEDGMENTS

This work was supported by the funds for the undergraduate innovative experiment plan of North China Electric Power University, and the Famous Teachers Cultivation planning for Teaching of North China Electric Power University (the Fourth Period).

REFERENCES

Beijing Municipal Bureau of Ecological Environment (n.d.). The Planning of the Constructed Wetland Water Purification Demonstration Zone in Wenyuhe Park Highlights the "Six Major Demonstrations".http://sthjj.beijing.gov.cn/bjhrb/index/xxgk69/sthjlyzwg/wrygl/834720/index.html. Retrieved on 2018-07-12.

Beijing Municipal Bureau of Ecological Environment (n.d.). Water Environment Function Zoning. http://sthjj.beijing.gov.cn/bjhrb/index/xxgk69/sthjlyzwg/1718880/1718884/hjgnqh/307590/index.html, Retrieved on 2009-11-01.

Cai, X., Huang, Q., Zhang, L. and Bai, L.Y. 2014. Causes of the Wenyu River in Beijing. Geol. China, 41(05): 1515-1521.

Cai, X., Men, B.H. and Li, C.J. 2019. Water quality evaluation of Wenyu river based on attribute recognition theory. Beijing Water, 2019(03): 26-30.

Cheng, W.G., Li, Y.B., Su, Y. and Wang, J. 2019. Comparative analysis of comprehensive water quality labeling index method with different weighting methods. J. Irrig. Drain., 38(11): 93-99.

Fovell RG. and Fovell M.Y. 1993. Climate zones of the conterminous United States are defined using cluster analysis. J. Climate, 6(11): 2103-2135.

Gu, J.Q., Zhang, W., Zhu, F., Chen, F., Su, G.Y. and Qi, H.N. 2016. WQI for water quality evaluation in Qingshan Lake. J. Zhejiang A&F Univ., 33(05): 890-898.

Howladar M.F., Chakma, E., Jahan, K.N., Islam, S., Numanbakth, M.A., Ahmed, Z., Chowdhury, T.R., and Akter, S. 2021. The water quality and pollution sources assessment of Surma river, Bangladesh using, hydrochemical, multivariate statistical, and water quality index methods. Groundwater Sustain. Develop., 12: 100523

Hulyal, S.B. and Kaliwal, B.B..2009. Dynamics of phytoplankton in relation to physico-chemical factors of Almatti reservoir of Bijapur District, Karnataka State. Environ. Monit. Assess., 153(1-4): 650.

Li, Y.H. and Wang, J.Y. 2007. Bai Wenrong, Hu Mangquan, Huang Lishan, Fang Shenghua. Water Quality Analysis and Utilization of Rain and Flood Resources in Wenyu River. Beijing Water, (02): 36-39.

Liang, Z.Q., Ma, M.T. and Du, G.F. 2013. Improved comprehensive water quality labeling index method based on information entropy weight and its application. Sichuan Environ., 32(03): 38-42.

Mogeng, H.P., Harremoes, J.L., Cour, J. and Eric, A. 1997. Wastewater Treatment Biological and Chemical Processes. Springer-Verlag, Berlin.

Ning Y.M., Yin F.N. and Li X.B. 2020. Application of several water quality evaluation methods in the mainstream of the Yangtze River. J. Southwest Univ. Nat. Sci. Edn., 42(12): 126-133.

Nong, X.Z., Shao, D.G., Zhong, H. and Liang, J.K. 2020. Evaluation of water quality in the south-to-north water diversion project of China using the water quality index (WQI) method. Water Res., 17(6): 611-636.

Oladipo Johnson, O., Akinwumiju Akinola, S., Aboyeji, O.S. and Adelodun Adedeji, A. 2021. Comparison between fuzzy logic and water quality index methods: A case of water quality assessment in Ikare community, Southwestern Nigeria. Environ. Challenges, 3: 100038

Pan, Y.H., Liang, Z., Wang H.N., Wan, L., Tan, L.J. and Ge, T.T. 2020. Analysis of the distribution characteristics and influencing factors of chemical oxygen demand in the waters adjacent to the Yangtze River. J. Xiamen Univ. Nat. Sci. Edn.m 59(S1): 63-68.

Sun, Y.K., Wang, L. and Qi, F. 2019. Analysis of water quality characteristics of reservoirs in Shandong province based on improved comprehensive water quality labeling index method. J. Lanzhou Univ. Nat. Sci. Edn., 55(06): 726-732.

Suriadikusumah, A., Mulyani, O., Sudirja, R., Sofyan, E.T., Maulana, M.H.R. and Mulyono, A. 2020. Analysis of the water quality at Cipeusing river, Indonesia using the pollution index method. Acta Ecol. Sin., 63: 458-491.

Wang, M. 2008. Comparison of several methods in water environment quality assessment. J. Bohai Univ. Nat. Sci. Edn., (01): 34-37.

Wang, Y.L., Liu, Z.J. and Liu, Y. 2010. Wenyu river water environment and water ecological construction. J. Beij. Water, (02): 10-17.

Wang, Y.Y. 2021. Analysis of the seasonal increase of ammonia nitrogen in Xixia Reservoir. Engineering Technology Research, 6(01): 251-252.

Xu, Z.X. 2005a. Research on evaluation method of comprehensive water quality labeling index for rivers in China. J. Tongji Univ. Nat. Sci. Edn., (04): 482-488.

Xu, Z.X. 2005b. Research on evaluation method of single-factor water quality labeling index for rivers in China. J. Tongji Univ. Nat. Sci. Edn., (03): 321-325.

Yang, L.R., Sun, R.H. and Chen, L.D. 2011. Analysis of the temporal and spatial differences in the pollution process of surface water bodies in the river basin and its impact mechanism: A case study of the upper and middle reaches of Wenyu River. Environ. Sci., 32(01): 73-79.

Zhong, J., Wei, Y.S., Wang, Y.W., Yu, M., Yang, Y., Xiao, Q.C., Yu, D.W., Zheng, X., Liu, P.B., Wei, W., Liu, J.G., Zhang and Zhu, M. 2011. Analysis of the impact of social and economic development on the groundwater in the Yongding River Basin (Beijing Section) and Wenyu River Basin. J. Environ. Sci., 31(09): 1826-1834.

Zhu, L.Y., Chen, Y.Y., Liu, J., Wang, Y.W., Wang, C.R., Wei, Y.S. and Zhang, Y.X. 2020. Temporal and spatial changes and interrelationships of water environment quality and phytoplankton community structure in Wenyu River. Environ. Sci., 41(02): 702-712.

Zhu, L.Y., Wang, Y.W., Yu, D.W., Wei, Y.S., Wang, C.R., Huang, B.B. and Wu, Zh. 2021. Application research of bypass off-line river purifier technology and system in Wenyu river rehabilitation. J. Environ. Sci., 41(01): 190-198.