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Evaluation on Water Pollution Prediction and Evaluation Method Based on Spectral Method

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Abstract: With the development of social economy, the Water Pollution (WP) caused by people's improper lifestyle is becoming more and more serious. Especially in recent years, WP has occurred frequently, and the protection of water environment health has become an urgent problem to be solved. WP prediction is the basis of water resources management and WP control, and ensuring the accuracy of WP prediction is extremely important for WP prevention and planning. In this article, the prediction of WP was studied; the detection method of WP based on spectral method and the prediction method of WP based on spectral method and improved Back Propagation (BP) Neural Network (NN) were proposed; the effect and application of the prediction method were studied. The research showed that the sum of square error and mean square error generated by the improved BP WP prediction method were 9.4 and 1.88 respectively, while the sum of square error and mean square error generated by the traditional BP WP prediction method were 299.49 and 59.9 respectively. Compared with the traditional BP WP prediction method, the improved BP WP prediction method had a more accurate prediction effect. At the same time, this article used the improved BP WP prediction method to evaluate the pollution risk level of the two water environments in Z City. The conclusion was that the water environment W belongs to the water environment with low pollution risk level; water environment R belongs to water environment with medium pollution risk level.

1. Introduction

With the acceleration of urbanization and industrialization, the discharge of domestic sewage and industrial sewage is increasing, and the water quality of natural water bodies is deteriorating. At this stage, the frequent water environmental pollution facts have reflected the serious fact of water environmental pollution. In the face of this situation, many scholars are studying the causes and trends of water environment quality change, and have carried out prediction research. Based on spectral method and BP NN, the prediction and evaluation of WP are studied in this article.

Many scholars have studied the prediction and evaluation of WP. YanYan used the ecological risk index as the evaluation endpoint index to evaluate how the accumulation of pollutants brings pressure to the water purification system [1]. Kumar Vinod evaluated and displayed the heavy metal pollution status of three different water bodies, namely Indus River, Bis River, Sutlej River and Harik Wetland, through multivariate statistical technology [2]. Li Xinyan estimated the WP load by combining the toxicity, release possibility and potential release of pollutants on the surface. This method considered both the in-place value and the mining value [3]. Tang Yankui reviewed the literature on emerging water pollutants published in 2018, focusing on the occurrence, detection methods, fate in the environment and ecotoxicity assessment of emerging water pollutants [4]. Chen SophiaShuang used the gradient assessment method, water quality index and statistical method to analyze the water quality of four typical urban rivers in Tanzania to evaluate the impact of urbanization on river water quality [5]. Solangi GhulamShabir used two standard numerical models and geospatial technology to evaluate the groundwater quality of 94 samples in the coastal areas of Pakistan [6]. In order to detect the pollution of water quality, Yang Huanhai built a multi-scale aquaculture water quality prediction model based on the design principles of decomposition, reorganization and integration [7]. The above scholars have carried out research on the prediction and evaluation of WP.

The prediction and evaluation of WP is of great significance to the prevention and control of WP and to the security of water environment. Bisht AnilKumar proposed a prediction model based on artificial NN for the WP of Ganges River, and carried out many experiments on the model [8]. Haghiabi AmirHamzeh investigated the performance of artificial intelligence technology, grouping data processing method and support vector machine in predicting the water quality components in southwestern Iran. Through experiments, it was proved that the artificial NN and support vector machine have the appropriate performance in predicting the water quality components [9]. In order to predict the dissolved oxygen and chlorophyll content of Small Prespa Lake in Greece, Barzegar Rahim developed a short-term memory and convolution NN model, as well as a hybrid model containing both [10]. Ayaz Muhammad proposed an artificial NN model to monitor and control the sea water quality in the coastal area of Karachi along the port, aiming at the problems of WP and aquatic ecosystem damage in the coastal area [11]. Leong WeiCong used support vector machine and least squares support vector machine models to study the water quality index. This method can immediately predict the water quality index using the physical data directly measured by the same prediction factor in the numerical method, without any sub-index calculation [12]. Hassan MdMehedi adopted the method based on machine learning when carrying out water quality prediction and evaluation, and conducted experimental research on the effect of this method [13]. Ge Simin evaluated the characteristics and risk levels of WP in eutrophic waters of 55 watersheds, and discussed the health risks caused by WP to human body [14]. Different from the above scholars, this article studies the prediction and evaluation of WP based on spectral method.

In order to solve the problem of WP, ensure the health of the water environment, and ensure the safety of people's domestic and production water, this article studied the prediction of WP based on the spectral method, and proposed the spectral method for WP detection and the improved BP NN for WP prediction, which provided the basis for the research of WP prevention and control planning. Compared with other studies, the improved BP WP prediction method proposed in this article improved the accuracy of the prediction results.

2. Evaluation of WP Detection and Prediction Methods

2.1. Evaluation of WP Detection Methods

At present, the detection technology of water environment quality has developed rapidly. At present, physicochemical method, electrochemical method and atomic absorption spectrometry are mainly used. In conventional water quality monitoring, the ion-selective electrode method and chemical method are still commonly used. This article summarizes some WP detection methods, as shown in Figure 1.

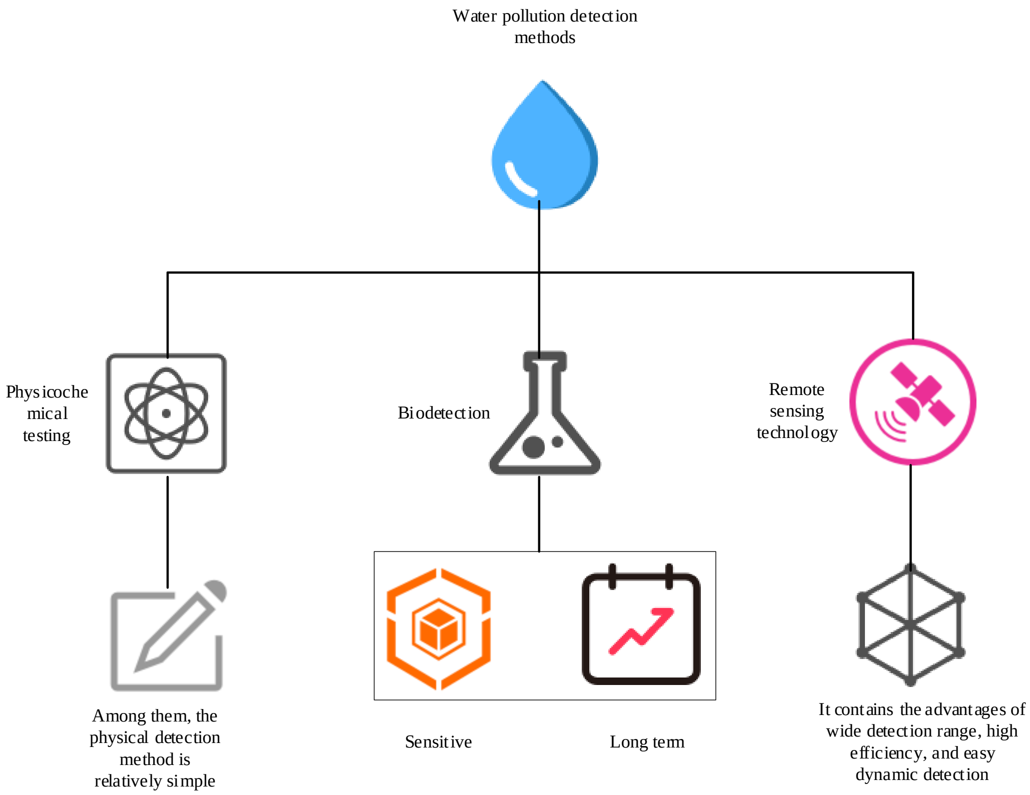


Figure 1. WP detection methods

Conventional physical and chemical detection: in the detection of surface water, it is easy to obtain physical detection indicators because the detection method is relatively simple. Conventional physical property index detection equipment includes turbidity meter, light filter, conductivity meter and multi-function water quality detector. Chemical detection is an important part of surface water detection. Because the government attaches great importance to the detection of toxic organic pollutants, this method has made great progress in the development of instruments and equipment. Some detection stations have installed large and medium-sized test benches, which can detect heavy metals and other elements on site.

Biological detection: biological detection is sensitive and long-term. At present, biological detection methods have been used in WP detection practice, mainly including biological index method and species diversity index method.

Remote sensing technology: according to the experience, statistical analysis, spectral characteristics, remote sensing band and ground observation water quality parameters, through the mathematical analysis of remote sensing band and ground observation water quality parameters, the inversion method of water quality parameters is established. The use of remote sensing technology can accurately reflect the distribution and change of water body in time and space, thus finding some pollution sources and pollutant migration characteristics that cannot be detected by traditional detection methods, and has the advantages of wide detection range, high efficiency, and easy dynamic detection.

2.2. Evaluation of WP Prediction Methods

This article summarizes the WP prediction methods, as shown in Figure 2.

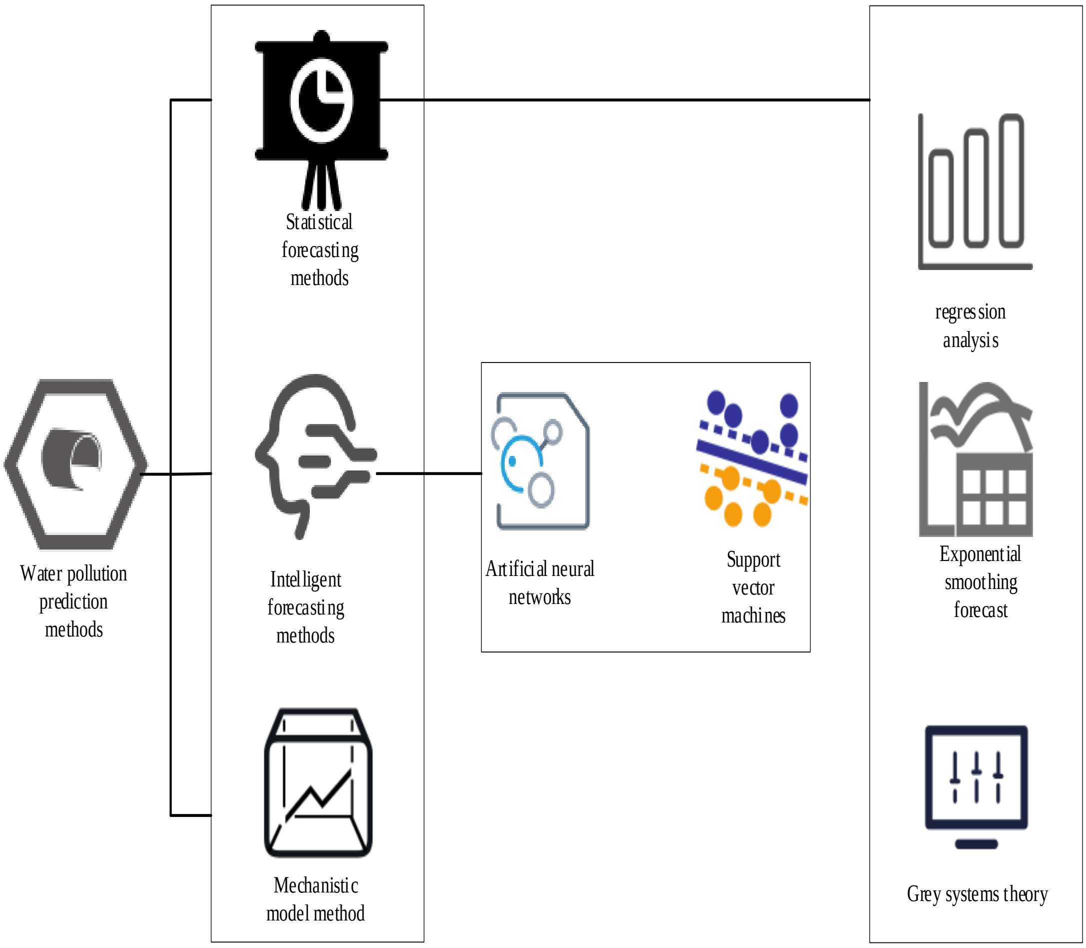


Figure 2. WP prediction methods

2.2.1. Statistical Prediction Method

Statistical prediction refers to sorting and analyzing the existing historical data, and using statistical methods to predict the future development trend and situation. At present, the commonly used prediction techniques include regression analysis and grey system theory.

Regression analysis: regression analysis is relatively simple, and more accurate results can be obtained using conventional statistical methods.

Exponential smoothing prediction: this method is easy to use and easy to operate, and is a relatively common time series prediction method. It combines the full-cycle average method with the moving average method. On the basis of using previous data, it obtains its mean value by introducing a simple weight coefficient.

Grey system theory: in WP prediction, its data demand is small. It does not need a lot of data, nor any data distribution rules, so its application is more and more extensive.

2.2.2. Intelligent Prediction Method

Due to the increasingly in-depth research on prediction methods, people are increasingly interested in using artificial intelligence to predict large-scale data. This article summarizes the intelligent methods for water environmental pollution prediction.

Artificial NN: it uses computer to simulate the activities of neurons and has good self-adaptability and self-learning ability. When learning or training, it would change its weight according to its own situation. Because of its strong ability in predicting WP, it has aroused great interest of scholars. Compared with the traditional statistical prediction, the model constructed by this method has higher prediction accuracy and can more accurately reflect the internal changes of water quality index.

Support vector machine: it can preview and correctly recognize according to specific samples. This method has good application prospects in classification, regression and other aspects, and has been widely used in many aspects. In addition, it has the advantage of processing complex and nonlinear data.

2.2.3. Mechanism Model Method

The mechanical model method is to decompose the internal laws of the actual object by understanding its characteristics, and establish a model to achieve the analysis and prediction of the target. The water quality analysis simulation program model can simulate one-dimensional unsteady flow of rivers and lakes and three-dimensional unsteady flow of rivers, and can find the transfer law of conventional pollution and toxic pollutants in water. When the river is in the state of complete mixing and stable flow, Streeter-Phelos model can predict the change of dissolved oxygen content.

3. WP Prediction Based on Spectral Method

3.1. WP Detection Based on Spectral Method

Fluorescence zone pretreatment: the three-dimensional fluorescence technology is used to detect the wastewater. Due to certain interference in the three-dimensional fluorescence zone itself, the spectral model would lack stability. Therefore, the first thing to do during the detection is to pretreat the three-dimensional fluorescence zone. The process is as follows: first, an appropriate three-dimensional fluorescence region is selected as the initial point to ensure that the position would not interfere with the reception of fluorescence signals. Secondly, the pretreatment of Rayleigh scattering, Raman scattering and Tyndall colloidal particle scattering is carried out. This step can effectively improve the detection sensitivity of three-dimensional fluorescence spectrum, lay the foundation for the establishment of the later trilinear model, and greatly improve the detection efficiency of water environmental pollution. Thirdly, the water samples in the 3D fluorescence region are smoothed, and the 3D fluorescence region is pretreated to extract the features of the water samples. The specific content is to select the appropriate coordinates of each 3D fluorescence frequency band and straighten them into line vectors. A water sample to be measured is placed in each row vector. Through the feature extraction of the polluted water samples, the matrix self-construction of the sample data is obtained. Using the rectangular self-boundary method, the water samples are obtained in three dimensions, and the original data of the three-dimensional spectrum are established by this method.

The water sample detection spectrum model is:

$$U = \sum_{m=1}^{m} a_m * b_m * c_m + F \tag{1}$$

Among them, U is the fluorescence spectrum; m is the sequence of harmful components contained in the wastewater; F is the residual matrix; a_m is the abscissa value of the harmful component in the fluorescence spectrum; c_m is the spatial coordinate of each harmful component.

3.2. Prediction and Evaluation of WP Based on Spectral Method and Improved BP NN

Based on the spectral method, this article proposes a water quality prediction method, which divides the WP data into training group and test group. The training group is about 70%, and the test group is about 30%. The network architecture of BP network is set and its parameters are determined. In this article, 3-layer network and 8 hidden layer neurons are set, and the learning rate is 0.02. On this basis, the number of neurons at different levels in the three-layer network is used to determine the optimal number of parameters required by the algorithm [15]. If the number of optimal parameters is d, its calculation formula is:

$$d = number_{in} * number_{hi} + number_{hi} * number_{ou} + number_{ou} \tag{2}$$

The fitness value of root mean square error calculation is selected:

$$MSE = \frac{1}{m} \sum_{p=1}^{m} \left(x_p - i_p \right)^2 \tag{3}$$

Among them, m is the number of training set samples; x_p is the true value; i_p is the predicted value.

First, the relevant parameters of Sparrow Search Algorithm (SSA) are initialized, and the structural parameters of BP NN are initialized. Secondly, the fitness function is established and solved. Taking the parameters of BP NN as the initial population and the mean square error as the fitness function, the minimum mean square error population is obtained. The positions of discoverers, participants and vigilantes are updated. By adjusting the fitness and updating the location of the population, the distribution of the population is closer to the optimal location. Finally, the termination conditions are set and whether the optimization has been completed is determined. If the requirements cannot be met, the fitness would be reset and the position of the group would be updated. When the conditions are met, the optimization is stopped. The optimal output parameters are combined into the BP NN, and then the network is trained to obtain the prediction results of the minimum root mean square error.

4. WP Prediction Effect and Risk Grade Evaluation Based on Improved BP NN under Spectral Method

On the basis of WP detection by spectral method, the improved BP WP prediction method and the traditional BP WP prediction method proposed in this article were used to predict the Chemical Oxygen Demand (COD) value in water quality and judge the effect of the two prediction methods. In addition, based on the COD content in the water detected by the spectral method, combined with the improved BP WP prediction method, this article evaluated the WP risk levels of the two water environments in Z City.

4.1. Effect of Two WP Prediction Methods

The improved BP WP prediction method and the traditional BP WP prediction method were used to predict the COD content in water quality. The detection results were shown in Table 1.

Table 1. Effects of two WP prediction methods

	COD true value (mg/L)	COD prediction value (mg/L)
Improved BP WP prediction methods	30 60 90 120 240	30.7 59.9 89.5 118.3 237.6
Traditional BP WP prediction methods	30 60 90 120 240	38.6 53.2 86.4 109.3 232.8

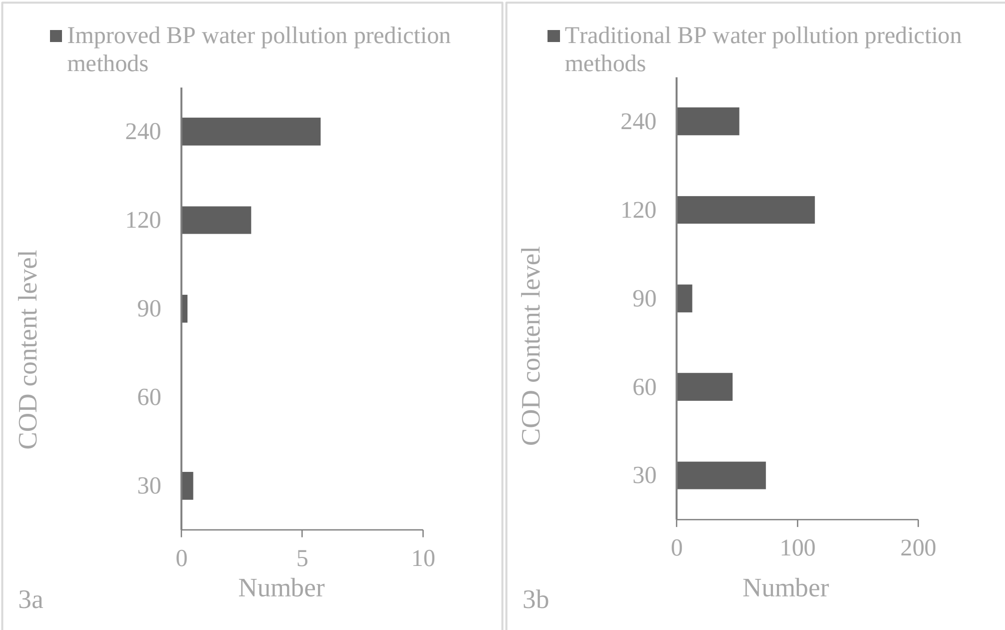
The effect of the WP prediction method was evaluated by using the sum of squares and mean square error. The predicted deviation values were shown in Table 2.

Table 2. The number of prediction deviations

	The number of prediction deviations(| |)
Improved BP WP prediction methods	0.7 0.1 0.5 1.7 2.4
Traditional BP WP prediction methods	8.6 6.8 3.6 10.7 7.2

As shown in Table 2, the predicted deviation value reflects the difference between the predicted value and the actual value of WP. From the prediction results, the prediction error generated by the two WP prediction methods is within the acceptable range, and both methods can play a role in WP prediction. However, compared with the traditional BP WP prediction method, the improved BP WP prediction method produces a smaller prediction deviation.

On the premise of using the sum of squares and mean square error to evaluate the WP prediction method, the square value of the prediction deviation value was first obtained, as shown in Figure 3.



3a. Improve the squared value of the prediction deviation value under the BP WP prediction method

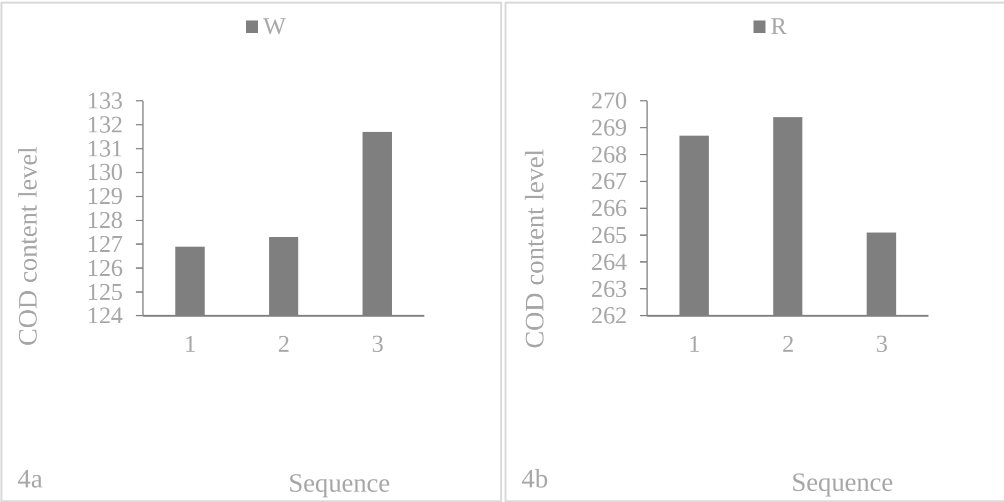
3b. Squared value of prediction deviation under traditional BP WP prediction method

Figure 3. The squared value of the deviation value

As shown in Figure 3, Figure 3a shows the square value of the prediction deviation value under the improved BP WP prediction method, and Figure 3b shows the square value of the prediction deviation value under the traditional BP WP prediction method. It can be seen from Figure 3a that under the improved BP WP prediction method, the square values of the predicted deviation values were 0.49, 0.01, 0.25, 2.89 and 5.76 respectively. According to the formula of error sum of squares and mean square error, the error sum of squares generated by the improved BP WP prediction method was 9.4, and the mean square error generated was 1.88. It can be seen from Figure 3b that under the traditional BP WP prediction method, the square values of the predicted deviation values were 73.96, 46.24, 12.96, 114.49 and 51.84 respectively. According to the formula of error square sum and mean square error, it can be concluded that the error square sum generated by the traditional BP WP prediction method was 299.49, and the mean square error generated was 59.9.

4.2. WP Grade Evaluation Based on Improved BP NN

Based on the COD content, the improved BP WP prediction method was used to evaluate the pollution risk level of the two water environments in Z City. The two water environments were respectively called W and R; the level with COD content below 200mg/L was called the low pollution risk level; the level with COD content of 200-500mg/L was called the medium pollution risk level; the level with COD content above 500mg/L was called the high pollution risk level. The assessment has been conducted three times, and the results were shown in Figure 4.



4a. Evaluation of WP level of W

4b. Evaluation of WP level of R

Figure 4. WP level evaluation based on improved BP NN

As shown in Figure 4, if the COD content level was taken as the basis for the WP level evaluation, it can be observed from Figure 4a that when the improved BP WP prediction method was used to predict the W water environment; the COD content levels obtained were 126.9, 127.3 and 131.7 respectively; the W water environment belonged to the water environment with low pollution risk level. It can be observed from Figure 4b that when the improved BP WP prediction method was used to predict the R water environment, and the COD content levels obtained were 268.7, 269.4 and 265.1, respectively. The R water environment belonged to the water environment with medium pollution risk level.

5. Conclusion

At this stage, a large number of WP emergencies have occurred, which has far exceeded people's tolerance for WP. Therefore, it is necessary to propose a method that can predict changes in the water environment, so as to achieve effective detection of water environmental quality, and thus provide support for WP prevention and control. This article analyzed the detection and prediction methods of WP, and studied the effect of this method after putting forward the WP prediction method based on spectral method and improved BP NN. It was concluded that the improved BP WP prediction method had better prediction accuracy than the traditional BP WP prediction method. In addition, this article also used this method to evaluate the pollution of water environment and drew relevant conclusions. Although the research in this article can provide some reference for relevant research, it also has limitations. Due to the different nature of each water body, the water quality analysis and prediction would be affected by a variety of external environments, such as time and space. This requires relevant personnel to scientifically select prediction models and develop new prediction methods under different water bodies and different pollution conditions. The research in this article is inclined to non-flowing water environment.

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Data Availability

Data sharing is not applicable to this article as no new data were created or analysed in this study.

Conflict of Interest

The author states that this article has no conflict of interest.

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