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Evaluation of Water Pollution Prevention and Control Project in the South-to-North Water Diversion Project Based on Machine Learning

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Abstract: During the South-to-North Water Diversion (SNWD) Project, water pollution (WP) is caused by industrial production, domestic garbage and other reasons, which may affect the role of the SNWD Project. Therefore, the WP governance project in the SNWD has become a very important social issue. Based on this, this paper studied the effect of WP prevention and control project of the SNWD Project, evaluated the water quality of the H section of the eastern route of the SNWD Project, proposed a prediction method of WP prevention and control effect based on machine learning (ML), and evaluated the water quality in the SNWD Project by combining the water quality index evaluation standard and fuzzy logic system. The results showed that the average absolute error of WP control effect prediction method was about 0.16, and the root mean square error was about 0.25. This method had certain accuracy. The water quality in the H section of the eastern route of the SNWD Project after prevention and control was good. The WP prevention and control project in the SNWD Project has played its due role, but there is still room for improvement.

1. Introduction

The serious scarcity of regional water resources has become an important issue, affecting the development of local economy and society. SNWD refers to the inter-basin transfer of water to make up for the shortage with surplus to achieve a reasonable distribution of water resources and effectively alleviate the water shortage in the north, thus promoting the coordinated development of the north-south economy, population and environment. The protection of water quality in the SNWD Project is not only related to the economic and social development of the region, but also to the water security and economic development of the whole water receiving area. Based on the above reasons, this paper researches the evaluation of the effect of the SNWD's WP prevention and control project, so as to fully guarantee that the SNWD Project can play the role of application.

Many scholars have studied water pollution and WP prevention. Sheng Jichuan studied the prevention and control of WP in the SNWD Project, pointed out its existing problems and potential solutions, and provided a special perspective for water pollution control methods [1]. Long Yan built a comprehensive risk assessment system with the integration of the analytic hierarchy process and the standard importance weight distribution theory [2]. Hou Wei studied the pollution of lakes and reservoirs in the SNWD, providing an important reference for the prevention and control of water pollution [3]. Haghiabi Amir Hamzeh used ML method to predict water quality and provided support for WP prevention [4]. Lakshmikantha Varsha reviewed in detail the latest work implemented in the field of intelligent water pollution monitoring system, and proposed a cost-effective and efficient intelligent water quality monitoring system based on the Internet of Things (IoT) [5]. Wu Li investigated the water pollution of Danjiangkou Reservoir, the source of the middle route of the SNWD [6].

Kamal Noha proposed a low-cost and labor-saving Nile water quality monitoring and early warning framework on the basis of the IoT for the lack of real-time water quality data affecting the emergency decision-making process in the water quality monitoring plan [7]. Ahmed Umair analyzed the conventional monitoring methods of water quality to understand the problems in depth, and analyzed the application of the IoT and ML technology in solving water quality problems [8]. Wang Yubao analyzed the water pollution caused by industrial development, and discussed the application of environmental complaint reporting system in WP prevention and control [9]. Wu Gaojie provided guidance for pollution reduction and theoretical basis for establishing and improving water pollution management [10]. Hassan Md Mehedi believed that the water quality index is the key indicator for the correct management of water resources. He used ML technology to study the water quality in various parts of India [11]. Thai-Nghe Nguyen used deep learning and short-term memory algorithms to develop a framework with a prediction model of the IoT system to monitor the water quality of aquaculture and fisheries [12]. The above scholars have carried out research on water pollution and WP prevention and control, but few scholars have specifically studied the WP prevention and control project in the SNWD. This paper has conducted an evaluation study on the prevention and control effect of WP prevention and control project in the SNWD.

In order to fully guarantee the water environment health of the SNWD and make the SNWD play its proper role, this paper analyzes the causes of water pollution in the SNWD. The prediction method of WP prevention effect based on ML and combined with fuzzy logic system is studied for the prevention effect of the SNWD's WP prevention project. Conclusions are drawn by assessing the water quality of the H-province section of the SNWD East Line. Compared with other studies, the accuracy of the WP prediction method used in this paper is higher, which supports the evaluation of the prevention and control effect of the SNWD's WP control project.

2. Causes of Water Pollution in the SNWD

Water pollution is caused by human activities, and its sources include industry, agriculture, and domestic waste, as shown in Figure 1.

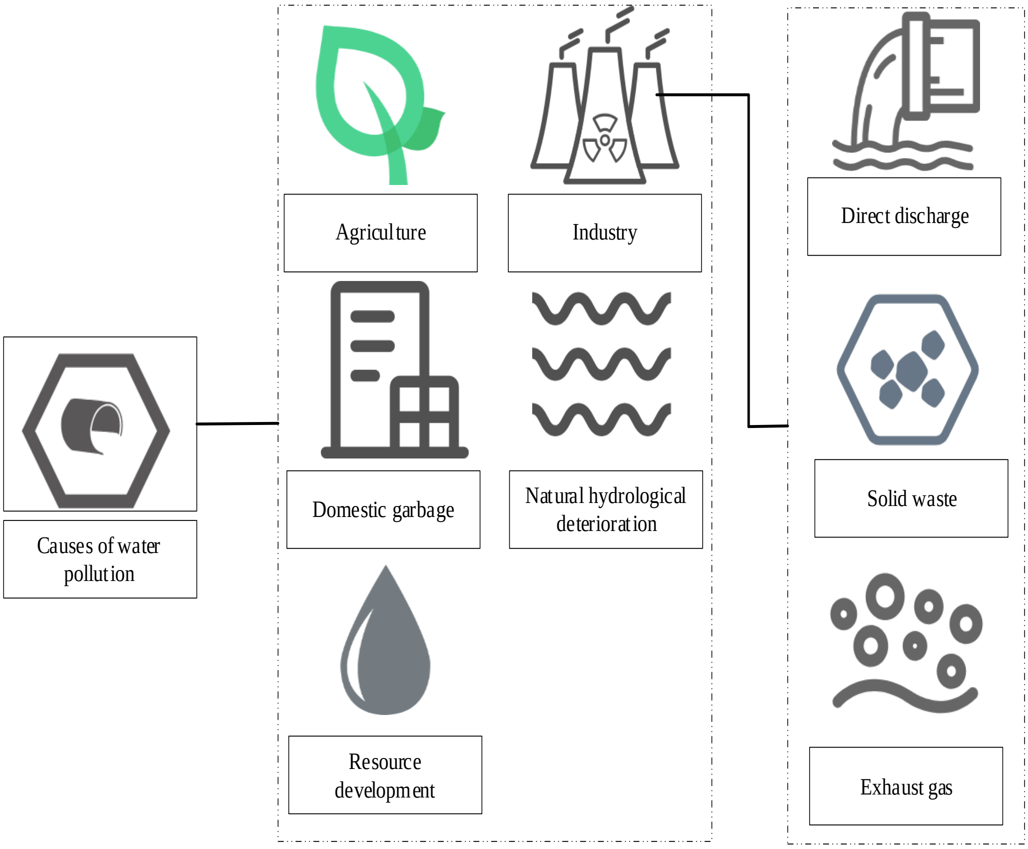


Figure 1. Cause analysis of water pollution

Industrial wastewater is a main factor of water pollution in human production processes. Due to its large number of pollutants and complex composition, these pollutants are not only difficult to purify in water, but also difficult to treat. The pollutants contained in industrial wastewater can vary greatly depending on the type of plant. Even in the same plant, the quality and quantity of pollutants vary due to different processes. In addition to the environmental pollution caused by the direct discharge of wastewater into water, industrial production also produces solid waste and waste gas, which indirectly affect the water environment.

Agricultural pollution is mainly due to the loose surface caused by plowing or reclamation, and a large amount of sediment enters water bodies when the soil and landscape are not yet stabilized. Another major cause is the use of pesticides and fertilizers, and only a few of these two play a role, while most of the remaining remains in the soil and air and flows into surface water with the washout of rainwater, causing pollution [13].

Domestic waste pollution is caused by dense population, domestic sewage, garbage, and exhaust gases.

The continuous deterioration of natural hydrological conditions, especially the intensification of geological changes such as soil erosion and soil sanding, has caused many rivers to break, dry up, shrink, or even disappear, and large amounts of sediment are deposited, resulting in ecosystem imbalance and water pollution.

Irrational development of resources can cause water environment pollution. With the continuous development of human social productivity, the exploitation of resources is becoming more and more intense, with a negative impact on the ecological environment, and the scarcity of water resources and the pollution of the water environment are becoming more and more serious. For example, overfishing can lead to the decline or even extinction of benthic organisms. Especially in summer, certain fishermen blindly expand the area of net box culture in order to make greater profits. Some fishermen have caused damage to many kinds of aquatic animals for profiteering, resulting in imbalance of the ecosystem and water pollution. In addition to overfishing, there is also the problem of water pollution caused by mining [14].

3. Machine Learning-based Method for Predicting WP Control Effects

The continuous wavelet transform equation is:

$$V_g(x,y) = |x|^{-\frac{1}{2}\int_{-\infty}^{+\infty} g(s)\psi^*} \left(\frac{s-y}{x}\right) es \tag{1}$$

Among them, $g(s)$ is the original signal; $V_g(x,y)$ is the wavelet transform coefficient; x is the scaling factor.

The discrete wavelet transform is calculated as:

$$_dX_{q+1}(c) = \sum_m l(m-2c)_d X_q(m) \tag{2}$$

$$_dE_{q+1}(c) = \sum_m h(m-2c)_d E_q(m) \tag{3}$$

The water quality information of the SNWD Project is collected, and the abnormal information is confirmed and rejected to make up for the omission. The base wavelet is selected, the number of decomposition layers m is determined, and the initial signal is decomposed. Use high-pass filtering to get m series sub-detail coefficients, use low-pass filter to generate the approximate coefficients corresponding to the wavelet parent function, reconstruct the coefficients to complete the transformation from wavelet to time domain. The information after wavelet decomposition is organized, and the long short-term memory (LSTM) model is trained using the wavelet decomposition of the water quality information of the SNWD, and the parameters are corrected until the accuracy requirements are met. Wavelet reconstruction is performed on the output data of the LSTM model to obtain water quality prediction values.

Fuzzy logic system is used to evaluate and analyze the water quality of the SNWD Project, and the corresponding formula is given.

$$U^p = if\ a_1\ is\ X_1^p, \dots, a_c\ is\ X_c^p \tag{4}$$

$$then\ b^p = i_0^p + i_1^p a_1 + i_2^p a_2 + \dots + i_c^p a_c \tag{5}$$

Where p is the number of fuzzy subsets.

Each input variable has the following degree of subordination.

$$\lambda_{X_q^p} = \exp\left[-\left(a_q - k_q^p\right)^2 / y_q^p\right] \tag{6}$$

Fuzzy calculation of each subordination degree:

$$v^p = \lambda_{X_1^p}(a_1)\lambda_{X_2^p}(a_2)\dots\lambda_{X_c^p}(a_c) \tag{7}$$

Calculate the output of the fuzzy neural network:

$$b_p = \sum_p \left[v^p\left(i_0^p + i_1^p a_1 + \dots + i_c^p a_c\right)\right] / \sum_p v^p \tag{8}$$

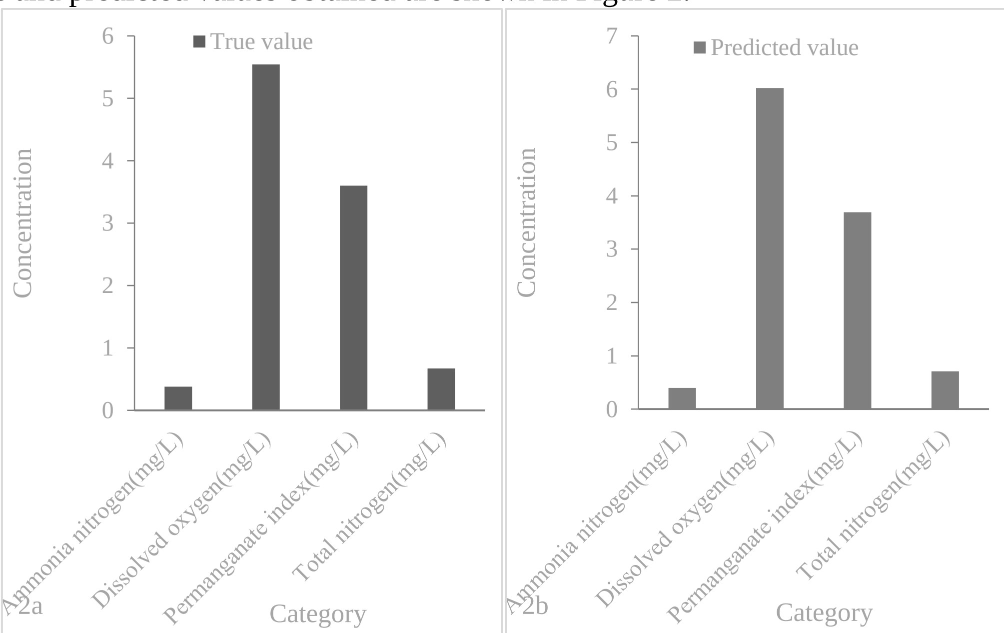
4. Accuracy of Machine Learning-based WP Prediction Method and Its Application in the Evaluation of the Effect of WP Control Project in SNWD

In this paper, the effectiveness of the ML-based WP prediction method was firstly investigated, and then the water quality condition of the H-province section of the SNWD East Line was assessed and studied based on this method. The water environment quality was classified into the categories of 1, 2, 3, 4 and 5. The effectiveness of the WP prevention and control project of the SNWD East Line was evaluated by monitoring the selected water environment water quality indicators such as ammonia nitrogen and dissolved oxygen. The water quality classification criteria are shown in Table 1.

Table 1. Water quality classification standard

Water quality monitoring and evaluation indicators	1	2	3	4	5
Ammonia nitrogen(mg/L)	0.15	0.5	1.0	1.5	2.0
Dissolved oxygen(mg/L)	7.5	6	5	3	2
Permanganate index(mg/L)	2	4	6	10	15
Total nitrogen(mg/L)	0.2	0.5	1.0	1.5	2.0

Using the method to predict the water quality situation in Province H section of the SNWD East Line, the true and predicted values obtained are shown in Figure 2.

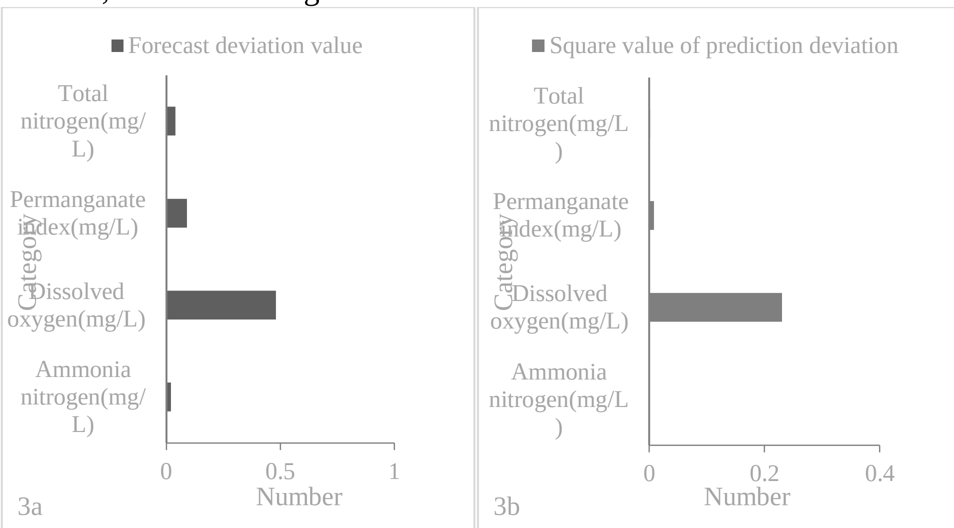


2a. True value *2b. Predicted value*

Figure 2. True versus predicted values

As shown in Figure 2, Figure 2a shows the real water quality indexes in the SNWD East Project, and Figure 2b shows the predicted water quality indexes using the ML method. From Figure 2a and 2b, it can be found that the gap between the real and predicted values of the four water quality indicators is not obvious.

The mean absolute error and root mean square error were used to evaluate the accuracy of the WP prediction method, and the prediction deviation values and squared prediction deviation values of the WP prediction method for four substances, such as ammonia nitrogen and dissolved oxygen, were firstly obtained, as shown in Figure 3.

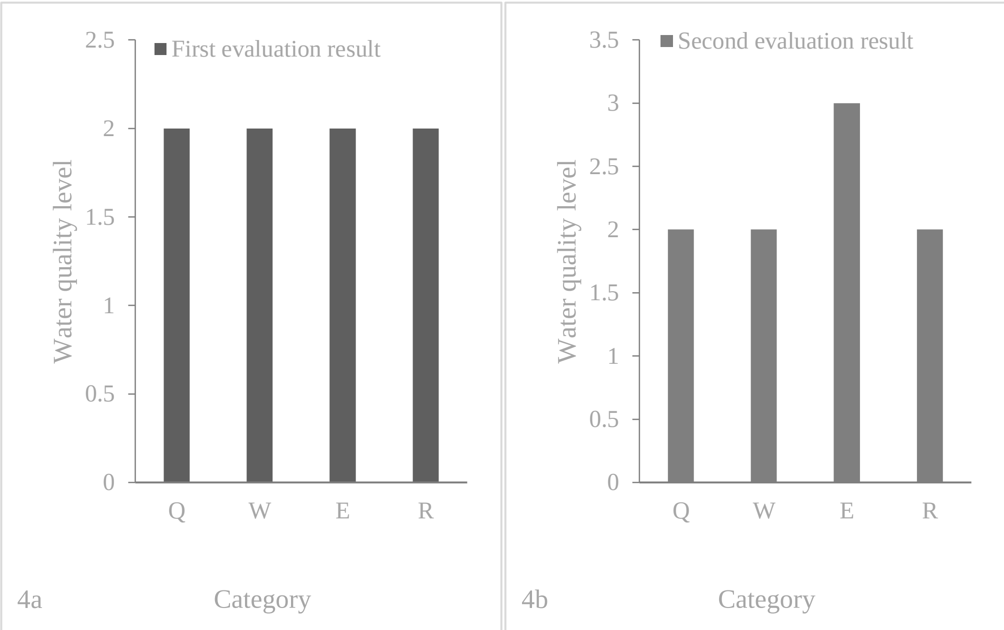


3a. Predicted deviation value *3b. Predicted deviation square value*

Figure 3. Predicted deviance values and predicted deviance squared values

As shown in Figure 3, Figure 3a shows the prediction deviation values of four substances such as ammonia nitrogen and dissolved oxygen by the WP prediction method, and Figure 3b shows the squared prediction deviation values of four substances such as ammonia nitrogen and dissolved oxygen by the WP prediction method. Combined with Figure 3a, the average value of the absolute value of the prediction deviation of the four substances was calculated, which means the average value of the absolute error of the prediction results was obtained. Among them, the prediction deviation of ammonia nitrogen was 0.02; the prediction deviation of dissolved oxygen was 0.48; the prediction deviation of permanganate index was 0.09, and the prediction deviation of total nitrogen was 0.04. The mean of the absolute error of the prediction results under the WP prediction method was calculated to be 0.16. According to Figure 3b, the average value of the square value of the prediction deviation of the four substances is calculated, and then the square root is carried out to get the root mean square error of the prediction result. The calculation shows that the root mean square error generated by the WP prediction method is about 0.25. According to the mean value of absolute error and root mean square error, the WP prediction method based on ML has high accuracy.

According to the water quality index assessment criteria, WP prediction method and fuzzy logic system, the water quality assessment was carried out twice for four of the sites in the eastern section of the SNWD Line in province H. These four sites were called Q, W, E and R. The assessment results are shown in Figure 4.



4a. Results of first assessment *4b. Results of second assessment*

Figure 4. Results of two water quality assessments

As shown in Figure 4, Figure 4a shows the first assessment of the water quality of the H-province section of the SNWD East Line, and Figure 4b shows the second assessment of the water quality of the H-province section of the SNWD East Line. Combining Figure 4a and Figure 4b, the water quality of the H-province section of the SNWD East Route can be evaluated as Class 2 level. It indicates that the WP control in the H-province section of the SNWD East Line is good, but the WP control in this region still needs to be improved.

5. WP Prevention and Control Guarantee and Enhancement Countermeasures of the SNWD Project

Implementing effective punishment: The implementation of environmental protection also depends on whether the relevant sectors pay attention to environmental protection. Judging from the current development situation, if the change of economic growth model is not achieved, the contradiction between development and water resource protection in the relevant sectors may continue for a long time. The supervisors of the relevant units should have some additional responsibilities, such as resigning if they have caused serious pollution during their tenure, or if they have failed in governance. To link environmental protection work and job performance, people who do not take environmental protection work seriously may not be promoted and reappointed. Let the people concerned pay the price for ignoring environmental regulations.

Implementation of compensation mechanism: SNWD requires a continuous and stable supply of quality water in the south, while some regions have raised their water quality standards to meet the demand of SNWD, which has reduced the ecological and environmental capacity of the region to a certain extent, thus restricting the local economic development. Some regions have extended the area of protected areas to a certain extent in order to protect water sources, which to a large extent restricts their own development. From the viewpoint of fairness and justice, the relevant departments should introduce regional compensation measures as early as possible to compensate for the economic loss caused by the water transmission area in the process of development.

Effective monitoring of interception and diversion work: Interception and diversion are important foundations to ensure water transmission projects. Sewage treatment companies and plants have to invest huge amount of money for pollution control because of this. If the interception and diversion work is not strictly monitored, it can probably cause pollution of water quality. Specifically, the operators of certain sewage treatment enterprises and factories, in order to save operating costs, resort to theft of sewage in order to reduce the cost of treatment, resulting in the interception and diversion project into a large water pollution transfer activities. Therefore, the relevant departments should improve the supervision link of the interception and diversion work as early as possible, and the factories and sewage treatment enterprises connected to the project should be strictly controlled, and compensation methods should be proposed when the quality of the water environment exceeds the standard.

Implementing water environmental protection policies that are conducive to the SNWD Project: First, the relevant departments should develop policies as soon as possible to promote the recycling of medium water. Reusing domestic wastewater not only can effectively solve water environment pollution, but also can effectively use wastewater and alleviate water shortage with significant economic and ecological benefits. However, due to the lack of relevant incentives, some enterprises and regions often give up using recycled water because it has no price advantage when measuring the price of recycled water and raw water. Even some areas of recycled water prices have exceeded the level of raw water, so that part of the recycled water can be recycled to be wasted. To this end, the relevant departments must introduce relevant policies and measures as soon as possible, and actively guide and support the use of recycled water, to promote the recycling of recycled water. Second, the relevant departments should gradually explore the policies of financial and tax collection, price, finance, trade and commerce to promote the prevention and sustainable development of WP, increase the efforts of legislation and economy, and perform and guide enterprises to fulfill their responsibilities in water environmental protection and WP themselves.

Upgrading WP control technologies: WP control technologies can be divided into two categories - physical and chemical methods. Physical technology is a more widely used wastewater treatment method, which includes two major categories - interception and diversion and silt dredging. In particular, sewage interception and diversion methods are widely used. When using interception and diversion methods, regular testing of equipment should be carried out frequently to ensure the normal operation of the equipment. In the treatment of the bottom sediment in the flow field, the bottom sediment dredging method can be adopted. This technique can greatly reduce the sediment in the water body and effectively control the nutrients in the water body, so that the water quality of the water body can be further purified and improved. Chemical methods mainly use algae removal methods and heavy metal fixation means to control water body pollution. Chemical algae removal methods can effectively remove algae and other microorganisms from water bodies, and can use copper sulfate and citric acid to inhibit the growth of algae. Heavy metal fixation means is to use alkaline substances to neutralize with acidic substances in water in order to control the acid-base value to ensure the stability of water quality. In the WP prevention and control of the SNWD Project, relevant departments should pay attention to scientific and reasonable technical means, increase investment, accelerate technology research and development, develop timely WP treatment technologies suitable for the SNWD Project, and further research on existing technologies [15-16].

6. Conclusion

By playing the role of the SNWD Project, it can effectively solve the shortage of water resources in the north, improve the carrying capacity of its water resources, contribute to the rational allocation of water resources in the north, and help ensure the water security and benign economic development in the north. However, the continuous growth of population and the rapid development of industrialization and urbanization, water pollution problems may have a certain impact on the water quality of the SNWD Project. Therefore, it is necessary to strengthen the protection of water quality. This paper firstly analyzes the causes of water pollution in the SNWD, and secondly proposes a prediction method for the WP prevention and control effect. The conclusions drawn in this paper are from the perspective of absolute error mean and root mean square error, the ML-based WP prevention and control effect prediction method has certain reliability in terms of accuracy. The WP prevention and control project of the SNWD has a good prevention and control effect, but the water quality of the SNWD project can still be further improved.

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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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