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Improved BP Algorithm Incorporating Genetic Algorithm for Water Pollution Prevention and Warning Application

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Abstract: In recent years, with the accelerated urbanization and industrial development, a large number of water pollution events have occurred in many regions, which have had a significant impact not only on the environment and socio-economics, but also on water quality. In this paper, the improved BP (back propagation) algorithm of genetic algorithm was used to improve the early warning system for water pollution prevention and control. This paper first introduced the current status of water resources monitoring and early warning mechanisms and the causes of sewage generation, followed by the transmission algorithm and the improved BP algorithm. Then the water pollution prevention and early warning system was designed by combining the two and the application effect was analyzed. It was found that the timeliness of water pollution early warning could be greatly improved after using the fused genetic algorithm and the improved BP algorithm. The water pollution prevention efficiency of water intake 1 was the highest, and its water pollution prevention efficiency was improved by 29% after adopting the water pollution prevention early warning system with fused genetic algorithm and improved BP algorithm. At present, the water pollution prevention and early warning system is more widely used, so the improved BP algorithm of genetic algorithm can be combined to improve the water pollution prevention and early warning effect.

1. Introduction

Due to the rapid development of industrial and agricultural production and population growth, a large amount of wastewater is discharged into rivers, causing serious water pollution, which directly affects the health of the population in the catchment area and the sustainable development of the local economy. Therefore it is an urgent task to establish an early warning and monitoring system for water pollution. The traditional water pollution early warning system only performs simple analysis and processing of detection data but not timely and effective comprehensive data analysis. The combination of neural network and genetic algorithm can solve such problems, which is determined by the characteristics of neural network and genetic algorithm. Using genetic algorithms for processing data can detect and remove some inconsistent data and votes. BP neural network can be used to build a water pollution early warning system, through adaptive training and neural network training to achieve the scaling accuracy requirements, using the completed training of the BP neural network to detect the measurement data to achieve the purpose of water pollution early warning.

The investigation and analysis of water pollution has many contemporary applications and has been analyzed by many scholars. Xu Zuxin analyzed urban river pollution control in developing countries [1]. Ahmed Shahid studied water pollution and its source, impact and management through a case study in Delhi [2]. Obinna Isiuku Beniah briefly reviewed the source, impact and progress in the use of aquatic plants for remediation of water pollution caused by heavy metals and organic pollutants [3]. Mekonnen Mesfin M discussed the phosphorus load of global human activities on fresh water and the related gray water footprint and water pollution level [4]. Singh Nirala studied the role of electrocatalysis in the remediation of water pollutants [5]. Mastrantonio Marina analyzed the pollution of drinking water caused by perfluoroalkyl substances [6]. Lee Chang-Gu studied the adsorption and photocatalytic degradation of water pollutants by porous electrospun fibers embedded with titanium dioxide [7]. However, these investigations of water pollution did not involve the analysis of prevention and early warning.

Genetic algorithms have also been applied in water pollution identification. Xia Xuemin used Taguchi design to optimize the parameters of genetic algorithm for water pollution source identification [8]. Liu Yi made qualitative and quantitative analysis of the relationship between water pollution and economic growth [9]. Morin-Crini Nadia reviewed the water pollution cases of new pollutants worldwide [10]. Li Z analyzed China's river director system and agricultural non-point source water pollution control [11]. Wu Jianhua used statistical and multivariate statistical techniques to track the water pollution sources and impact factors of a rapidly developing city on the Loess Plateau of China [12]. He Xiaodong studied the surface water pollution of the loess plateau in central China [13]. Chen Sophia Shuang analyzed the water pollution assessment of urban rivers under the urbanization of East Africa [14]. However, there is no research on integrating the improved BP algorithm of genetic algorithm for application.

In order to prevent and warn water pollution in a timely manner, genetic algorithm and improved BP algorithm methods are used in this paper. The effects of the traditional water pollution prevention and warning system and the water pollution prevention and warning system with the fusion of genetic algorithm and improved BP algorithm are compared and analyzed, and finally it is found that the water pollution prevention and warning system with the fusion of genetic algorithm and improved BP algorithm can greatly improve the water pollution warning timeliness and water pollution prevention efficiency of each water intake. Compared with other results, this paper combines the improved BP algorithm with genetic algorithm to be applied to water pollution prevention and early warning.

2. Current Status of Water Resources Monitoring and Early Warning Mechanism and Causes of Sewage Generation

The water resources monitoring and early warning mechanisms and the causes of effluent generation are recorded to Figure 1.

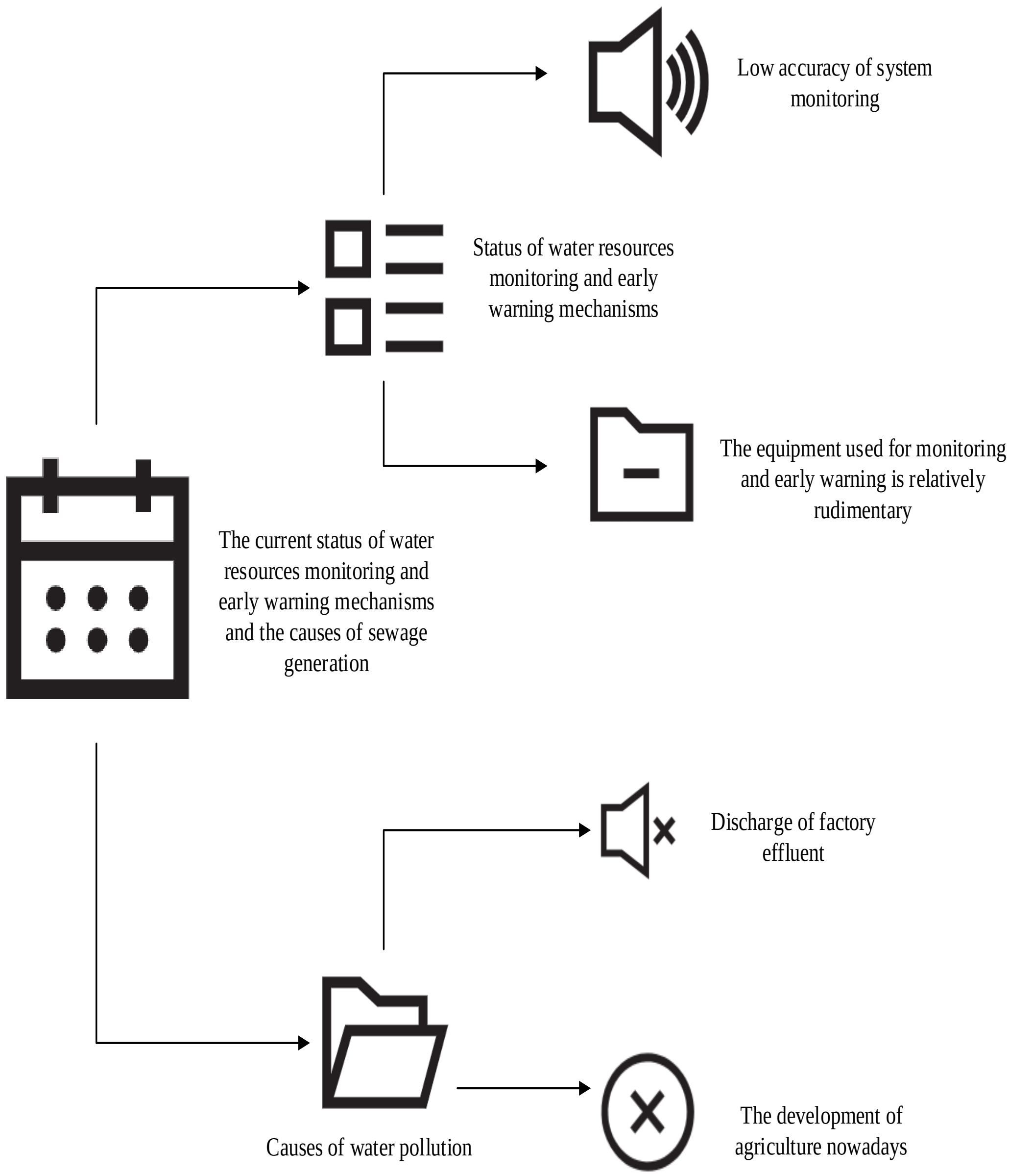


Figure 1. Current status of water resources monitoring and early warning mechanisms and causes of effluent generation

2.1. Status of Water Resources Monitoring and Early Warning Mechanism

2.1.1. Low System Monitoring Accuracy

Existing water pollution monitoring and early warning mechanisms are mainly in the form of manual monitoring, which often requires the use of large amounts of manual resources to monitor water sources on a regular basis, and requires observers to visit different water sources to conduct preliminary checks on the relevant water quality conditions. Although this monitoring method can be effective to a certain extent in monitoring water resources, observers can be uncomfortable with the situation, making monitoring does not achieve a certain degree of accuracy, and is likely to be ineffective in controlling water quality, causing a great threat to the lives and property of people using contaminated water.

2.1.2. Rudimentary Monitoring and Warning Equipment

In many areas where water resources are quite backward, the equipment used for water monitoring and early warning is often rudimentary, and its accuracy is far from the requirements of monitoring and early warning [15]. This not only wastes resources, but also means that water pollution monitoring and early warning mechanisms cannot be used effectively. In addition to the late start of related work, the lack of basic technology has hampered the ongoing specific monitoring work to some extent, affecting the accuracy of the specific monitoring work.

2.2. Causes of Water Pollution

2.2.1. Discharge of Factory Effluent

The management of water resources has many risks in the context of indiscriminate discharge of industrial effluents and is often faced with prevention and control problems [16-17]. Today, industrialization is proceeding rapidly and some foreign-owned companies, joint ventures and sole proprietorships are operating, but they all end up discharging a variety of effluents [18]. Although the government has banned the discharge of sewage according to the regulations, some companies still take a chance and carry out secret discharges, causing serious pollution of rivers. Currently, the government has introduced a policy of factory renovation, and some companies that have a significant impact on the urban environment are undergoing relocation and resettlement.

2.2.2. Current Development of Agriculture

The development of agricultural production often cannot avoid the use of large amounts of pesticides and chemical fertilizers, which inevitably bring pollution to water resources. The animal husbandry industry is also developed and animal wastewater is also produced in large quantities. This wastewater is discharged directly into rivers without treatment, which is the direct cause of urban river pollution.

2.3. Harm Caused by Water Pollution

Water pollution can be divided into organic and inorganic contamination [19-20]. Petrochemicals, such as benzene and its congeners, phenol and other organics, are biodegradable and many of them are carcinogenic and very harmful to human health. Contaminated water usually includes agricultural irrigation water, organic animal wastewater, municipal waste, and domestic wastewater from urban areas. Pollutants that leach into water increase chemical oxygen demand, biochemical oxygen demand, and in severe cases make the water cloudy, odorous, and undrinkable. They degrade the physicochemical properties of water by converting nitrogenous organic matter into nitrite and nitrate through microorganisms. Long-term consumption of water with high nitrate concentration can lead to digestive disorders, methemoglobinemia in infants, suffocation and even death.

Water contains excessive amounts of metallic elements such as mercury, chromium, cadmium, arsenic, lead and their compounds. Excess amounts of each of these substances can cause serious harm to humans and animals. These metallic elements and their compounds accumulate in natural organisms, that is., they are carried through the biological chain and eventually lead to higher concentrations and greater harm. They can be enriched in vital parts of the body, such as the liver, kidneys and spleen, as well as the brain and bone tissue. Long-term use of water with excessive mercury concentrations can lead to diseases such as hepatitis, nephritis and mobility problems, often resulting in death or other lifelong health problems.

3. Genetic Algorithm and Improved BP Algorithm

3.1. Genetic Algorithm

3.1.1. Fundamentals

Genetic algorithms simulate the mating and reproduction of species and the genetic mutations that occur during the inheritance process. This algorithm starts with an arbitrary initial population and uses random selection, interpolation and mutation operators to create new individuals that are better adapted to their environment. After several generations of genetic evolution, the optimum is eventually reached. All individuals in the population are possible solutions to the optimization problem, and the optimal individual is the optimal solution. As an intelligent optimization method, the algorithm can perform global search and converge to the optimal solution. It is robust to complex nonlinear problems, can be transformed, and can also use continuous or discrete functions as the optimization objective function. The principle of this algorithm is simple, and it is feasible and applicable. The advantages of the genetic algorithm are documented in Figure 2.

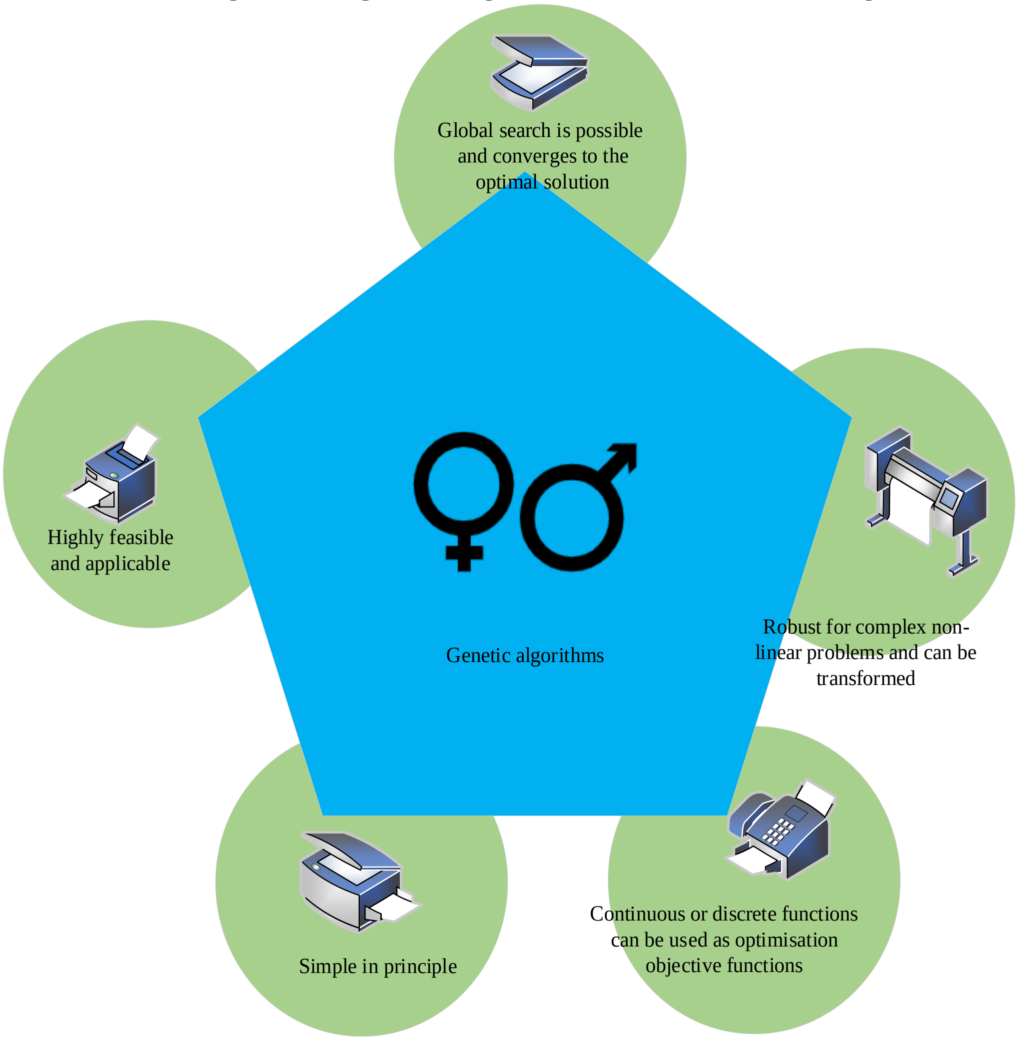


Figure 2. Advantages of genetic algorithms

3.1.2. Calculation Process

A water pollution wave can be defined as a diffusion and convection process that occurs when pollutants converge instantaneously in a river. Typically, this process can be described by a one-dimensional convective mathematical diffusion equation. However, information about the hydrology and topography of the river is often lacking when implementing an emergency response to an incident. Therefore, the equation must be simplified as follows: the initial state of the river and the pollutant concentrations at the two endpoints are simplified to zero for the total amount of pollutants entering the river. The river is simplified to a steady flow in a homogeneous environment and is reduced to a straight channel. The pollutants are uniformly mixed in the river and slightly attenuated along the river channel. When a multi-point source event occurs, the simplified mathematical equation for the one-dimensional convection of the pollutant concentration distribution along the river confluence can be obtained as follows.

$$\frac{\partial S}{\partial t}+\eta\frac{\partial S}{\partial x}=E_x\frac{\partial^2 S}{\partial^2 x^2}-KS+\sum_{j=1}^{n}N_j\alpha\left(x-x_j\right) \quad (1)$$

In equation (1), t represents time.

The inverse of the source can be transformed into an optimal solution of a discrete nonlinear function with the following equation.

$$\min\sum_{j=1}^{m}S\left(x_j,M_j,\bar{x}_j,U\right)-\bar{S}\left(\bar{x}_j,U\right) \quad (2)$$

Since the direction of individual evolution in the genetic algorithm is the direction of increasing fitness, and equation (2) requires that the direction of change of the variables is the direction of decreasing the value of the objective function, the objective function must be transformed into a fitness function. The equation is as follows.

$$M=\frac{1}{\left[S\left(x_j,N_j,\bar{x}_j,U\right)-\bar{S}(\bar{x}_j,U)\right]^2} \quad (3)$$

3.2. Improved BP Algorithm Incorporating Genetic Algorithm

BP neural network is one of the most important models of artificial neural networks with self-organization, self-adaptation and self-learning features. Its application has made unprecedented progress in solving nonlinear problems. The strength of the connections between neurons in the network is represented by the magnitude of the weighting coefficients. The weighting coefficients can be continuously modified by learning from training examples, and the connection strength between neurons increases with the number of training examples and repeated training. The system uses an implicit layer, and the error function of the BP neural network is quadratic, with local minima and slow convergence.

For genetic algorithms, it can easily happen that the algorithm converges too early and the solution found is a global suboptimal solution, which requires a small local search for each generation of the current optimal solution to consider whether a better solution exists. the BP algorithm is a complementary algorithm in which one algorithm has a strong global search capability and the other has a strong local search capability.

4. Water Pollution Prevention and Control Early Warning System

4.1. System Composition

The improved BP algorithm incorporating genetic algorithm for water pollution prevention and early warning system consists of three parts. Genetic algorithm module: processing the detection data to generate optimized samples; BP network module: training the samples to get a BP network that meets the requirements; early warning processing module: processing the measurement data by the obtained BP network and predicting the water pollution situation based on the processing results. It is summarized in Figure 3.

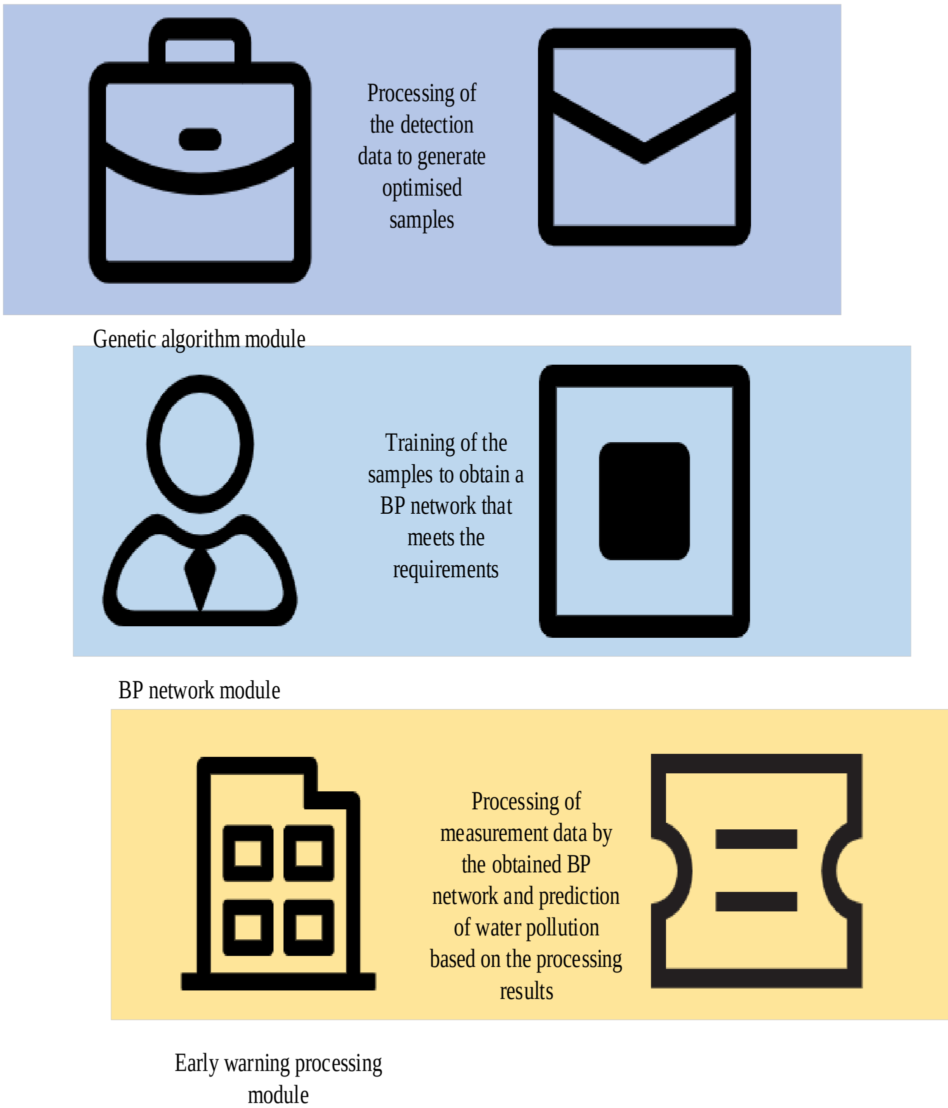


Figure 3. System design

4.2. Core Functions

In order for the early warning system to achieve the desired effect of water pollution prevention and control, it must ensure that the monitoring data from local monitoring stations can be effectively accessed remotely and the relevant information is comprehensively and effectively stored in the relevant database. Real-time monitoring of water environment quality indicators and processing of scattered quality data are achieved by analyzing and comprehensively storing real-time dynamic data in the database. Therefore, in the design process, it is necessary to ensure the effectiveness of its following functional modules.

4.2.1. Transmission Data Reception Function

In the design process, considering the monitoring information of the lowland water environment monitoring station, the detection method is different and the information is complicated, so it is impossible to transmit it in the whole system, so the information of the lowland water environment monitoring station should be processed in the first time. It is possible to describe the water environment according to the water quality and set the IP address of the applicator through the transmission of the Internet system. In order to avoid affecting the authenticity and integrity of the information received by the system during transmission, the system should be connected to its own monitoring layer to evaluate the information of the data obtained, which also plays a decisive role in the quality of the monitoring of the water environment monitoring station.

4.2.2. Water Quality Warning Boundary Setting Function

The reasons for the frequent occurrence of water pollution events vary, and there are more adopted early warning systems for different reasons of water pollution occurrence, and the resulting responses are different. In order to ensure a correct and effective response when water pollution is detected by the monitoring system, the response detection value must be predetermined in the system and specific ratio calculations must be established. Usually, it is necessary to first set the water quality alarm thresholds related to water turbidity, pH, organic content, etc., so as to determine the degree of contamination and the level of response.

5. Application Effect of Water Pollution Prevention and Control Early Warning System

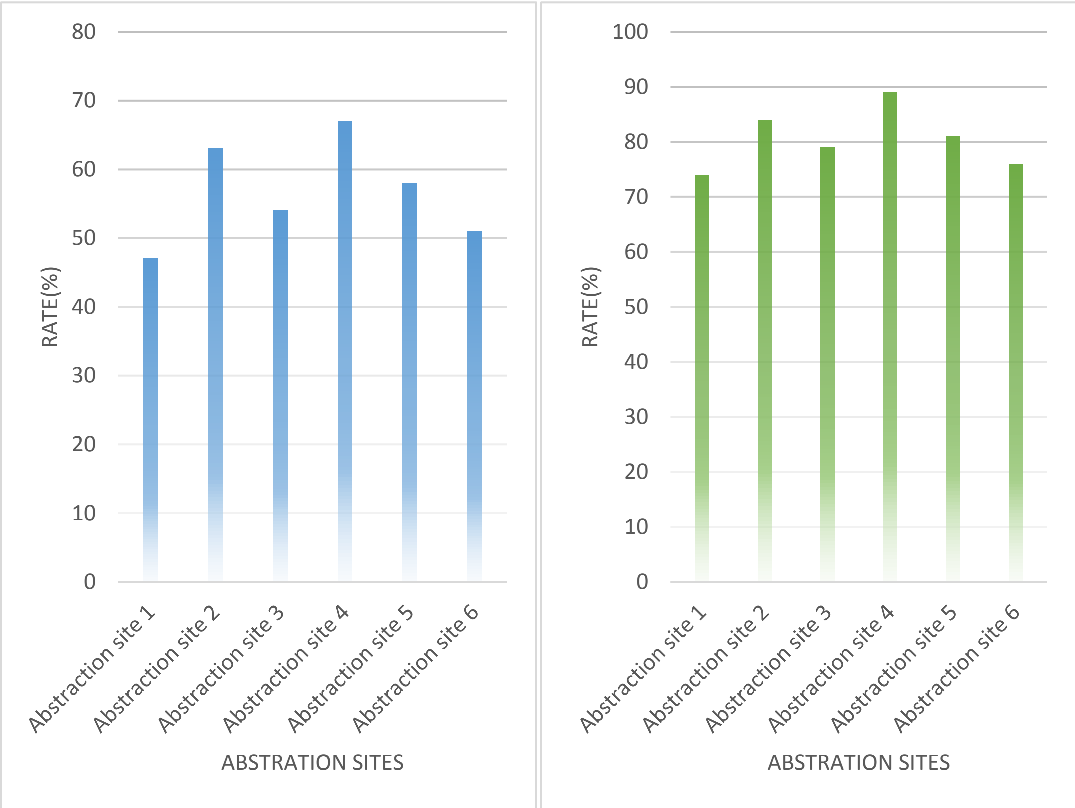
In order to improve the early warning effect of water pollution control, six different abstraction sites were selected for investigation and analysis in this paper, and the preliminary monitoring results of water obtained at different abstraction sites were recorded to Table 1.

Table 1. Water pollution at abstraction sites

Water abstraction sites	Contamination
Abstraction site 1	Light pollution
Abstraction site 2	No pollution
Abstraction site 3	Highly polluted
Abstraction site 4	No pollution
Abstraction site 5	Light pollution
Abstraction site 6	Moderate pollution

5.1. Timeliness of Water Pollution Warning

If the pollution at the water intake can be warned, people can be alerted in time so that water pollution can be prevented in time. Based on this the warning timeliness of the water pollution prevention and control early warning system using the traditional water pollution prevention and control system and the water pollution prevention and control early warning system incorporating genetic algorithm and improved BP algorithm are recorded in Figure 4.



A. Timeliness of water pollution warnings using traditional water pollution prevention and control early warning system

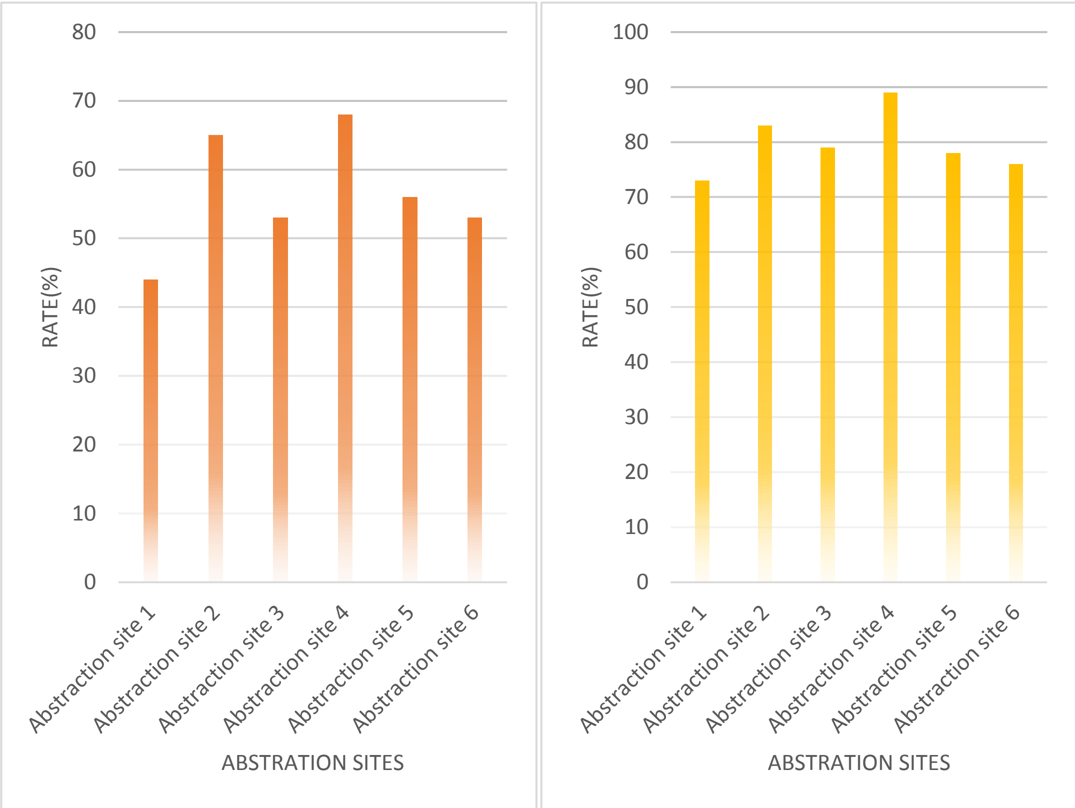
B. Timeliness of water pollution warnings using water pollution prevention and control early warning system with the fusion of genetic algorithm and the improved BP algorithm

Figure 4. Timeliness of water pollution warnings using different water pollution prevention and control early warning systems

In Figure 4, A represents the water pollution warning timeliness using the traditional water pollution prevention and control early warning system, and B represents the water pollution warning timeliness using the water pollution prevention and control early warning system with the fusion of genetic algorithm and the improved BP algorithm. In the traditional water pollution prevention and control early warning system, the water pollution warning timeliness of each water intake is at a low level, which is lower than 70%, but, after using the water pollution prevention and control early warning system with fusion genetic algorithm and improved BP algorithm, the water pollution warning timeliness of each water intake is higher than 70%. The timeliness of water pollution early warning can be greatly improved by adopting the fusion genetic algorithm and the improved BP algorithm.

5.2. Water Pollution Control Efficiency

Water pollution problems need to be prevented and managed in a timely manner when they occur, so water pollution prevention efficiency plays a good role in treating water pollution problems. The findings of water pollution prevention efficiency are recorded in Figure 5.



A. Water pollution prevention and control efficiency of water pollution prevention and control early warning system using traditional water pollution prevention and early warning system

B. Water pollution prevention and control efficiency of the water pollution prevention and control early warning system incorporating genetic algorithm and improved BP algorithm

Figure 5. Water pollution prevention and control efficiency using different water pollution prevention and control early warning systems

In Figure 5, A represents the water pollution control efficiency using the conventional water pollution control early warning system, and B represents the water pollution control efficiency of the water pollution control early warning system incorporating the genetic algorithm and the improved BP algorithm. The water pollution prevention efficiency of intake 1 is improved by 29% after adopting the water pollution prevention early warning system with the fusion of genetic algorithm and improved BP algorithm. The water pollution prevention efficiency of intake 2 is improved by 18% after adopting the water pollution prevention early warning system with fused genetic algorithm and improved BP algorithm. The water pollution prevention efficiency of intake 3 is improved by 26% after adopting the water pollution prevention early warning system with the fusion of genetic algorithm and improved BP algorithm. The water pollution prevention efficiency of intake 4 is improved by 21% after adopting the water pollution prevention early warning system with the fusion of genetic algorithm and improved BP algorithm. The water pollution prevention efficiency of intake 5 is improved by 22% after adopting the water pollution prevention early warning system with the fusion of genetic algorithm and improved BP algorithm. The water pollution prevention efficiency of intake 6 is improved by 23% after adopting the water pollution prevention early warning system with fused genetic algorithm and improved BP algorithm. The water pollution prevention efficiency of intake 1 is the highest.

6. Conclusion

In order to improve the effect of water pollution prevention and early warning, this paper uses the improved BP algorithm of genetic algorithm to improve the water pollution prevention and early warning system, and designs experiments to compare and analyze the water pollution warning timeliness and water pollution prevention efficiency of the traditional water pollution prevention and early warning system and the water pollution prevention and early warning system with fused genetic algorithm and improved BP algorithm. The water pollution control early warning system with fused genetic algorithm and improved BP algorithm can greatly improve the water pollution warning timeliness and water pollution prevention efficiency of each water intake, which indicates that the fused genetic algorithm and improved BP algorithm have good application space in water pollution control early warning.

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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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