Scholar Publishing Group
Water Pollution Prevention and Control Project
https://doi.org/10.38007/WPPCP.2020.010206
ISSN 2790-2730 Vol. 1, Issue 2: 52-62

Ant Colony Algorithm in the Planning of Water Pollution Control System

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Keywords: Water Pollution, Prevention and Control system, Ant Colony Algorithm, Industrial Pollution

Abstract: To eliminate pollution, protect the environment and prevent the continuous deterioration of water quality, people began to conduct in-depth exploration of various wastewater treatment technologies, and invested a lot of funds, material and financial resources on this basis. Large-scale sewage treatment projects should avoid direct discharge of untreated wastewater into water bodies. People's awareness of water pollution should be enhanced to make significant contributions to the prevention and control of water pollution. However, with the deepening and extensive water pollution prevention and control projects, human beings have to pay more costs to solve these problems. Many researchers provided new ideas for the application research of water pollution prevention and control system planning, which was the research direction and basis of this paper. This paper analyzed how to plan the water pollution control system, and carried out academic research and summary on the application of analyzing the water pollution control system planning. This paper established an algorithm model, and put forward relevant algorithms to provide theoretical basis for application research in water pollution prevention and control system planning. At the end of the paper, a simulation experiment was carried out, and the experiment was summarized and discussed. Through the establishment of water pollution prevention and control system for city X, it was concluded that the effectiveness of prevention and control of pollution sources in this city was mostly more than 85% after the use of this system. The effectiveness of prevention and control of industrial pollution sources increased by 34%; the effectiveness of prevention and control of agricultural pollution sources increased by 31%; the effectiveness of prevention and control of living pollution sources increased by 20%; the effectiveness of prevention and control of living pollution sources increased by 21%. At the same time, with the in-depth study of ant colony algorithm, the application research of water pollution prevention and control system planning also faced new opportunities and challenges.

1. Introduction

Pollutants from human production and life spread into rivers, lakes, reservoirs, harbors and groundwater through the water cycle, thus causing a large amount of water pollution also makes water resources more scarce, and even threatening the survival and sustainable development of human beings. In order to eliminate pollution, protect the environment and prevent the continuous deterioration of water quality, people have conducted in-depth research on various waste water technologies. However, as water pollution prevention and control projects are carried out in depth and widely, human beings have to pay more costs to solve these problems. Faced with the increasingly serious water pollution situation, many developed countries have gradually realized the importance of environmental issues and taken decisive actions. This has not only made the water pollution in major cities effectively curbed and some areas of water pollution has been significantly improved. The basic experience of pollution control can be summarized in two aspects: On is the management. Through the establishment of authoritative institutions, the river can be uniformly planned and effectively managed; the other is technology. Field visits can obtain a large amount of original information, and then the analysis of information and accumulation are the basis for the use of modern science and technology, which constantly improve the effect of comprehensive remediation.

In the planning of water pollution prevention and control system, Ahmed Shahid's research showed that awareness campaigns involving citizens and strict implementation of environmental laws by relevant institutions were appropriate solutions to control environmental degradation. He suggested that there should be an appropriate waste treatment system to deal with the waste before it enters rivers and water bodies [1]. Tan Poh-Ling believed that the natural properties of the Great Barrier Reef were rapidly declining due to the serious threat of water pollution and climate change. He also analyzed the environmental, social, political and legal conditions that led to or hindered the successful management of diffuse water pollution [2]. Oral Hasan Volkan provided many suggestions, such as improving water quality, increasing biodiversity, gaining common social benefits, improving urban microclimate and advancing indoor climate to reduce energy consumption [3]. Wang Faming's research argued that water pollution was becoming a major and serious problem in the world. However, considering that traditional wastewater purification methods were chemical, energy and technology-intensive, it was still a considerable problem to find reliable and energy-saving methods [4]. Li Zhou studied that as part of the efforts to control water pollution, the local government introduced the river director system. That is to say, designated individuals were responsible for protecting specific watercourses [5]. He Xiaodong's research found that nitrate was an important pollutant in surface water, and the hydrochemical evolution of surface water was controlled by rock weathering and evaporation crystallization [6]. Singh Nirala believed that since various chemicals produced and used in daily life could eventually pollute the water flow, it was challenging to provide clean water for drinking water or industrial water [7]. The above studies achieved good results, but with the continuous updating of technology, there were still some problems.

The application research of ant colony algorithm in water pollution control system planning has the following achievements. Mutlu Ekrem established a random package design with two factors to evaluate the effect of different adsorption materials on the phytotoxicity of wheat growth parameters [8]. The research results of Nait Amar Menad showed that the established simulation agent was robust and was an effective alternative to simulate the performance of numerical simulation in the optimization of water-alternating gas injection. Both genetic algorithm and ant colony algorithm were very effective in combination optimization of water-alternating gas injection process [9]. Azad Armin studied the applicability of particle swarm optimization and continuous domain ant colony optimization in estimating water quality parameters of three stations along the river [10]. Janga Reddy M believed that in the past three decades, the development and use of meta-heuristic algorithms to solve various optimization problems in the field of water resources engineering achieved tremendous growth [11]. Mehzad Nazli proposed a three-objective optimization algorithm called cluster non-dominated archive ant colony optimization, and evaluated the efficiency of the algorithm through the test function [12]. The above research showed that the application of ant colony algorithm had a positive effect, but there were still some problems.

In this paper, the application of ant colony algorithm in the planning of water pollution control system was studied. Firstly, it analyzed how to plan the water pollution control system. Its related contents were given and the water pollution control system was designed. By using the relevant algorithms to provide the theoretical basis for the experiments, finally a comparative analysis of the water pollution control system of city X under the use of ant colony algorithm was made to provide reference significance for such research.

2. Planning of Water Pollution Control System

Water pollution control is a very broad concept. Macroscopically, it includes the coordination and balance of population planning, economic development and water environment quality. Geographically, it includes the integrated development of the entire watershed of a river and its water pollution control, but also water quality and sewage treatment at a certain scale. Even the planning, design and operation of a specific wastewater treatment facility, the scope and nature of the issues involved vary, thus forming a variety of systems. In the pollution management of industrial pollution sources, the recovery of pollutants, the economics of transport distance, the economics of treatment scale, the economics of treatment efficiency, the self-purification capacity of the water body and other factors are mutually affected and constrained. If the relationship between them can be well coordinated, the water quality standards can be made, and the total cost of the system can be reduced, which is also the starting point and purpose of water pollution control planning issues.

Considering the water pollution area as a whole and the pollution prevention and control plan for the system, there is a certain causal relationship or input and output relationship between it and the environmental quality indicators. This reflects, to some extent, the maximum discharge of the indicator, as well as the difference between the indicators and reasonable emissions. Factors affecting the cost of water pollution control include the economics of sewage transport distance, the economics of treatment scale, the economics of treatment efficiency, the dilution of water quality and the environmental benefits of natural treatment capacity. They interact and constrain each other in water pollution prevention and control. The design goal of the water pollution control system is to coordinate the interrelationship between the various elements, and to rational use its natural pure water capacity, so as to maximize its technical and economic benefits, and achieve the maximum reduction in construction costs.

In water pollution management, the planned costs are the total cost of the wastewater treatment plant and the cost of water transmission. If the number of wastewater treatment plants is used as a variable to shift from large to small. That is to say, from decentralized to centralized, the wastewater treatment cost of the system would decrease significantly, while the wastewater transmission cost would increase rapidly. In the planning of water resources management system, the best water environment quality should be found at the least cost. The size of a wastewater treatment plant is closely related to the infrastructure and operating costs it requires to treat a unit volume of wastewater. In addition to the economies of scale, its treatment effect also has economic benefits. The so-called economic effect refers to the cost and treatment effect required to remove each mass of pollutants in the treatment process. The natural purification capacity of a water body and the environmental capacity of a water body can be considered as a natural resource for the treatment of pollution. In order to reduce the burden of wastewater treatment to reduce the cost of wastewater treatment, the rational use of these resources should be fully considered when developing a water pollution control plan. The establishment of a wastewater treatment plant of the right size and treatment level in the right location through a specific system would not only meet the water quality requirements but also reduce the total cost of the whole system.

Water pollution control system planning can be specified as Figure 1.

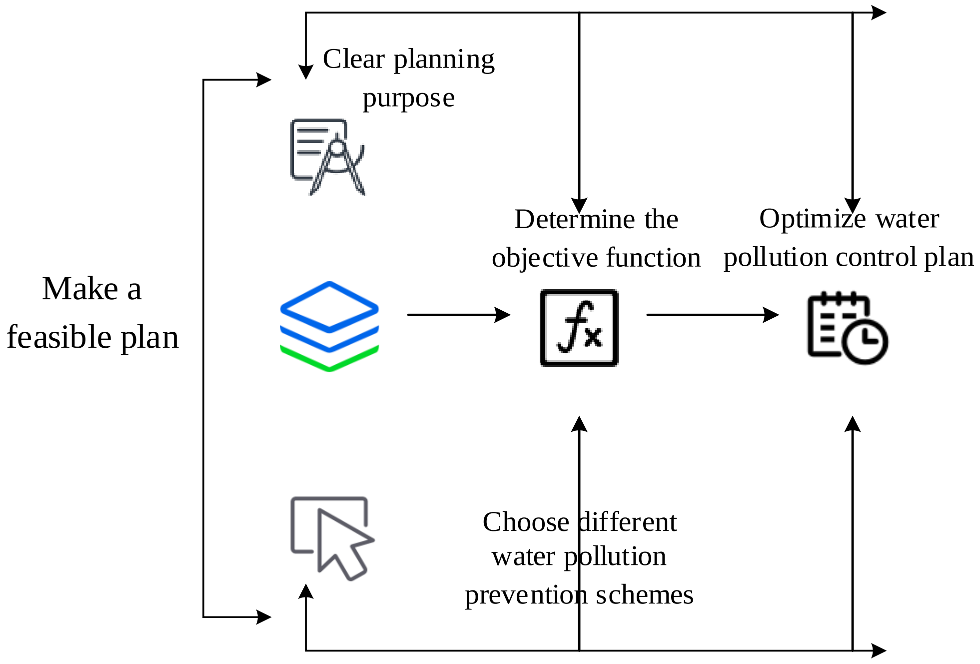

Figure 1. Water pollution prevention and control system planning

(1) Clarifying the purpose of planning

Planning purposes include planning scope, water body use function, water quality standards, and technology level. The use of each water body depends on its specific role. It is necessary to develop different water quality indicators according to the local social, economic and technical factors, and according to the different uses of different areas and river sections to meet people's needs for water.

(2) Optimizing water pollution prevention and control program

To optimize the water pollution prevention and control program, it is necessary to establish the quantitative relationship between the pollution source generation system, the environmental quality of the water body and the pollutant control system and to study the mathematical model of the water body pollution. Its main content includes pollution quantity calculation model, water quality simulation model, and optimization calculation model. It also contains model conceptualization, model structure identification, model parameter estimation, model sensitivity analysis, model reliability verification and application.

(3) Selecting different water pollution control programs

The main elements of the water pollution control system planning are the analysis of the production process of the pollution source, the analysis of the water use system and the analysis of the drainage system. Different water pollution prevention and control schemes should be selected and the economic and technical feasibility study should be carried out, and then the whole project should be planned and designed.

(4) Determining the objective function

Through the objective function of determining the regional water quality standards, the water quality constraints, technical constraints and planning methods should be determined, and the optimal water quality planning scheme should be gave. After the optimal water quality planning scheme is proposed, this scheme must be coordinated with the water pollution control engineering scheme in order to achieve the best scheme acceptable to the local economic and technical strength. Through a series of quasi-optimal scheme of water quality simulation, the best scheme of environmental benefits can be got [13].

(5) Developing a workable plan

In the process of water resources management, the optimal solutions obtained by mathematical methods are often not applied to practical applications. Due to the improvement of water quality, the effects of water ecological balance, human health, tourism and other aspects are difficult to be measured by the cost function. In addition, water quality indicators are the main factors affecting the quality of the environment, while other environmental, political, economic, technological and other factors on the environment are also the main factors of environmental quality. Therefore, it is necessary to coordinate and develop a feasible plan for each objective in a unified manner.

3. Application in the Planning of Water Pollution Control Systems

The goal of the water pollution control system planning is to coordinate the relationship between the components within the system to meet the water environmental quality requirements with the lowest water pollution control costs. The environmental quality of water bodies is part of the regional environmental quality, and the water quality standards of water bodies are developed according to the political, economic, cultural and other conditions of a region, which is an important basis for water pollution control system planning. The basic application of water pollution control includes the following aspects, as shown in Figure 2.

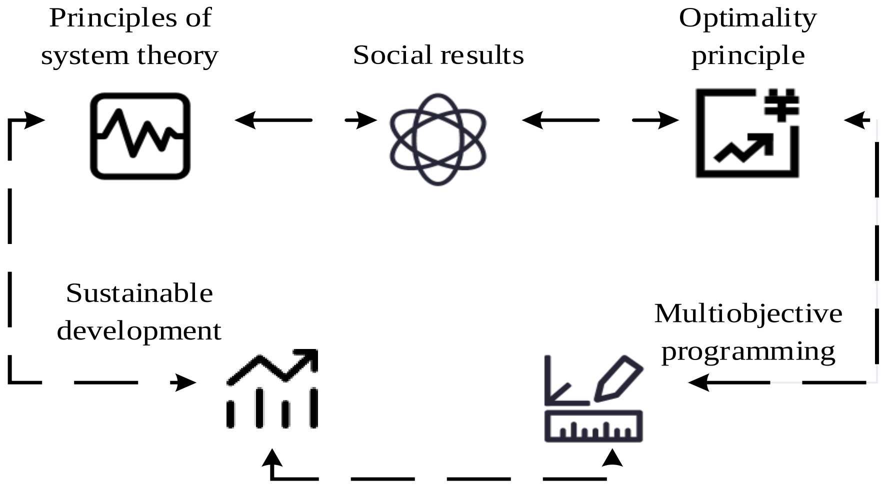

Figure 2. Basic application of water pollution control

(1) Principle of system theory

Water pollution prevention and control is a comprehensive social, economic and natural environment of complex, and large system engineering, which is also a multi-factor, multi-objective, multi-variable open system. The system planning should be designed according to the principles of system theory. According to the current situation and planning of the water pollution collection and treatment system, and combined with the physical and geographical conditions of urban water bodies and the current situation of water conservancy facilities construction, the area is divided into different sewage collection networks and independent sewage treatment plants are set up [14].

(2) The principle of social benefits

There are benefits and costs associated with the results of water pollution control. These can be divided into two broad categories-revenues and expenditures associated with human activities, including pollutant recovery, treatment activities, pipeline conveyance, wastewater treatment, and other water environment treatment activities, regarding the social benefits and costs of water pollution and treatment.

(3) Optimal principle

Finding the optimal solution when carrying out rational planning is the key to achieving harmony between environmental quality and economic benefits. Therefore, the principle of optimality in water pollution control planning is a very important principle.

(4) The principle of sustainable development

Sustainable development is a development that meets the needs of the present without threatening the needs of the next generation. This concept clearly indicates two basic ideas: The first is human development, especially for the poor; second, there should be restrictions on development, but it should not endanger the development of future generations. The idea of sustainable development is a fundamental change towards a sustainable development strategy.

(5) Multi-objective planning principle

Water pollution prevention and control planning and design should not only achieve certain water quality indicators, but also meet certain social, political, economic and technical needs. The nature of water pollution prevention and control planning determines that the problem belongs to multi-objective planning. Different planning objects can be selected according to different problems, such as the multi-objective combination planning model of regional water pollution control. The treatment investment, operation cost, income and pollutant consumption are combined for comprehensive optimization.

The advantage of multi-objective decision making is its flexibility, which can provide decision makers with a variety of decision options and decision information. The optimal scheme sought by the single-objective optimal model only tells the decision-maker that it must do so; multi-objective decision-making can provide a set of effective solutions and relevant information for decision makers. Multi-objective decision-making is undoubtedly compatible with modern enterprise management practice.

4. Method of Ant Colony Algorithm in Water Pollution Control

In the same reach, the pollutants that are difficult to decompose are discharged instantaneously, and the change of pollution concentration at x is calculated by Laplace integral conversion method:

$$L(x,t)=\frac{M}{A\sqrt{4\pi Et}}\exp\left[-\frac{(x-ut)^2}{4Et}\right] \tag{1}$$

In the formula, x is the distance of the measurement point from the projection point; t is the time calculated from the zero point of the time of the emitted pollutant; E is the longitudinal discontinuity factor.

Tracer is a non-degradable substance. It is injected into the river in the upstream section and is diluted as it flows downstream by diffusion of water, so that a relatively smooth tracer concentration profile is measured further down the profile. The distribution of this process line is also an important indication of the migration and diffusion properties of the river [15]. The variation pattern of pollutant concentrations at different sites x can be seen from the above formula. An objective function is determined in the case of determining the distribution of L(x, t).

$$S = f(E) = \sum_{n=1}^{m} C^t(x,t_n) - \frac{M}{A\sqrt{4\pi E t_n}} \exp\left[-\frac{(x-ut_n)^2}{4Et_n}\right] \tag{2}$$

When S≥0, E can be obtained from the following formula.

$$\min S = \min f(E) \tag{3}$$

In this paper, the above problem was solved using an ant colony algorithm. This problem contains only one uncertain variable. During the initialization of the ant colony algorithm, the pheromone τ is the same for each path. Visibility η_{nm} from node n to node m is chosen as the reciprocal of the objective function of node m. The probability of ant selection is p_{nm}:

$$p_{nm} = \frac{\tau_{nm}(t)^{\alpha}\eta_{nm}(t)^{\beta}}{\sum_{s\in A_k}\tau_{ns}(t)\eta_{ns}(t)} \tag{4}$$

In the formula, $A_k = \{0,1,\ldots,n-1\}$ represents the next available node for ants to choose. α and β are both 1.

When an ant completes a cycle, the orbital intensity of its pheromone gets changed as follows.

$$\tau_{nm}(t+1) = \rho\cdot\tau_{nm}(t) + \Delta\tau_{nm}(t,t+1) \tag{5}$$

5. Discussion of the Water Pollution Control System for City X

Water pollution mainly comes from water pollution sources, which generally refer to equipment and facilities that discharge pollutants in water bodies or cause adverse effects on water bodies. According to the reasons for their generation, they can be divided into two types of natural sources and man-made sources. Man-made sources of pollution can be divided into industrial, agricultural, living, transportation and other sources of pollution according to the way of human activities. In this paper, city X was selected as the subject of experimental discussion. A river within the city was randomly selected and its pH value was estimated at 5-25m water depth. The comparison was made based on the detailed data in the water report. The proposed ant colony algorithm was combined with the water pollution house system and the effectiveness of the prevention and control before and after its use in the city was compared and analyzed. Finally, a summary and discussion were made based on the experimental results. Table 1 showed three types of wastewater discharges from four locations in city X.

Table 1. Waste water discharge of 3 types at 4 places in X city

	Industry (100 million/ton)	Agriculture (100 million/ton)	Life (100 million/ton)
Goal 1	54	36	12
Goal 2	36	24	16
Goal 3	41	19	11
Goal 4	63	31	14

The method to determine the river water pollution is as follows: By taking 500ml of river water as a sample, its pH value was measured, and the pH value of normal river water was 7-8. If the pH value was high, it meant that the alkalinity was too strong, if the pH value was too low, it meant that the acidity and alkalinity were too strong. The specific analysis was shown in Figure 3.

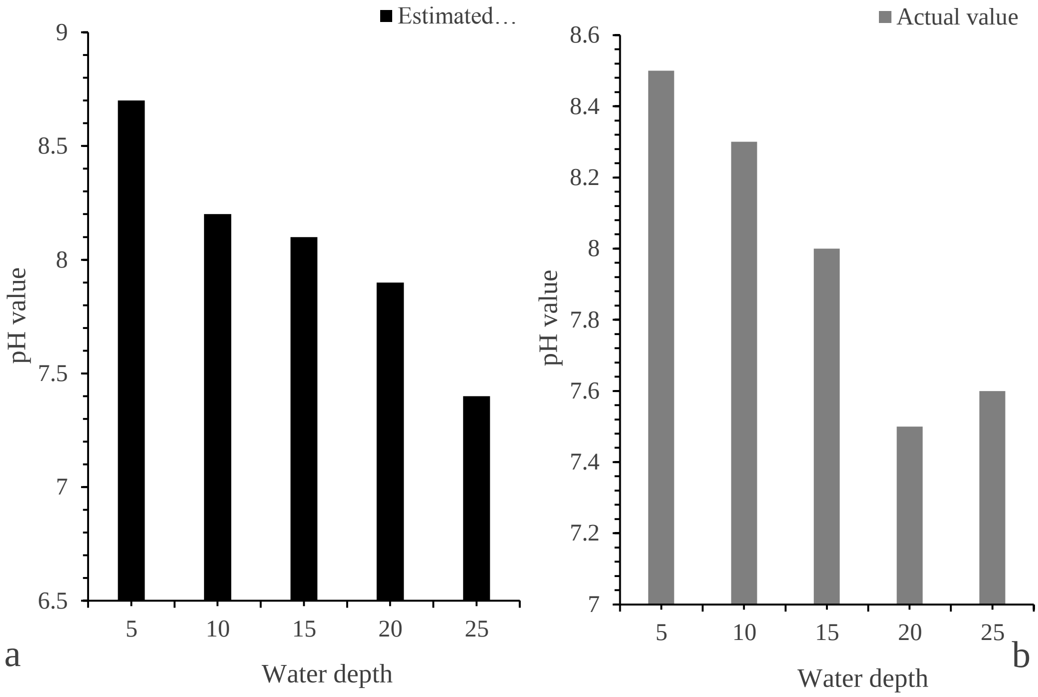

Figure 3a. Estimated pH value

Figure 3b. Actual value of pH value

Figure 3. Comparison of pollution degree between estimated value and actual value

Figure 3a showed the estimated pH value of the river at 5-25m water depth and Figure 3b showed the actual pH value of the river at 5-25m water depth. From Figure 3, the estimated contamination of the stream at 5 m depth was 8.7, which was 0.7 more than the highest normal pH value. At 5 m depth, the stream appeared alkaline, and the estimated contamination of the stream at 10 m and 15 m depth were 8.2 and 8.1, which were 0.2 and 0.1 more than the highest normal pH value. At 10m water depth, the river also appeared alkaline; when the water depth of the river was 20m and 25m, its PH value was within the normal range.

Compared with the estimated values, the actual values of pH at 5m, 15m and 20m water depths were lower than the estimated values, while the actual values of pH at 10m and 25m water depths were higher than the estimated values. After the above pH monitoring at 5 water depths, it could be roughly concluded that the pH value of shallow water would mostly be higher or lower than the normal pH value, while the pH value of deep water would mostly lie within the range of normal pH value.

From the above, it could be concluded that the sources of water pollution were mostly industrial, agricultural, living, and transportation. The comparison of pollution prevention effectiveness of the city's water pollution control system before and after using the ant colony algorithm was analyzed by these four sources, as shown in Figure 4.

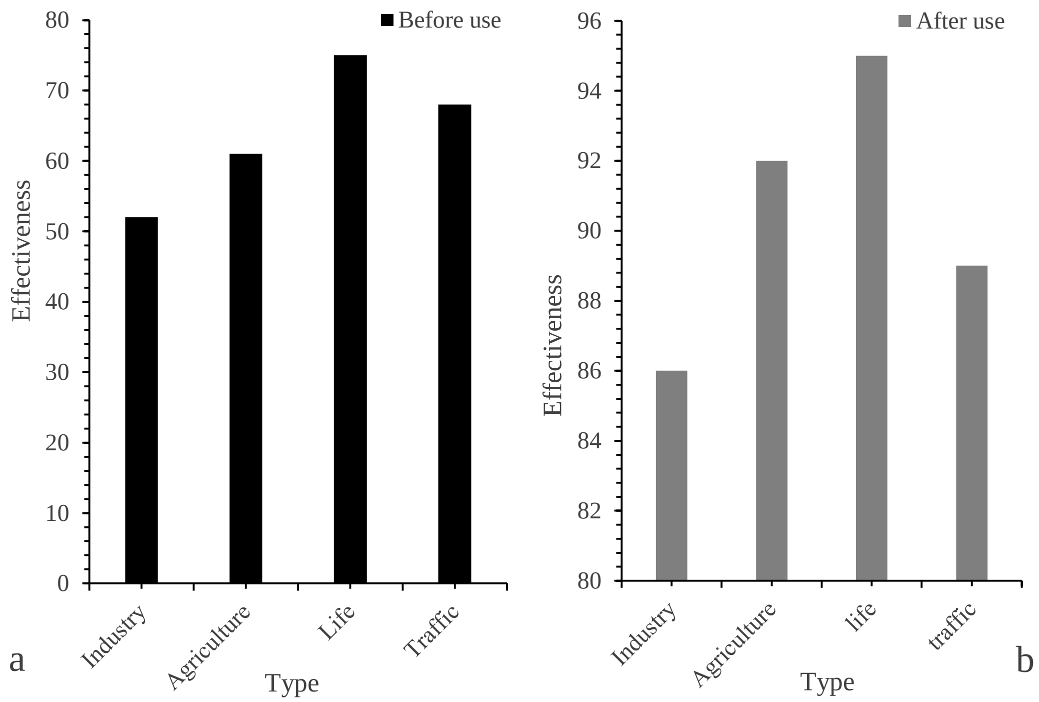

Figure 4a. Effectiveness of water pollution prevention and control before use

Figure 4b. Effectiveness of water pollution prevention and control after use

Figure 4. Comparison of the effectiveness of pollution prevention and control before and after its use

Figure 4a showed the effectiveness of the city's prevention and control of the above four pollution sources before use, and Figure 4b showed the effectiveness of the city's prevention and control of the above four pollution sources after use. It could be seen from Figure 4 that the prevention and control effectiveness of the four types of pollution sources in the city was mostly below 80% before use. Among them, the effectiveness of prevention and control of industrial pollution sources was the lowest; after use, the control effectiveness of the four types of pollution sources in the city was mostly more than 85%. Among them, the effectiveness of prevention and control of industrial pollution sources increased by 34%; the effectiveness of prevention and control of agricultural pollution sources increased by 31%; the effectiveness of prevention and control of living pollution sources increased by 20%; the effectiveness of prevention and control of traffic pollution sources increased by 21%. From the effectiveness of prevention and control of pollution sources, it could be seen that the city was mostly a development-oriented city dominated by industry. Therefore, the prevention and control of its industry was relatively difficult. The effectiveness of prevention and control of industrial pollution sources increased significantly in the later period of use. Therefore, the suggestion for it was that the adjustment of industrial structure could solve the serious problem of water pollution.

In summary, this paper investigated the application of ant colony based algorithm in the planning of water pollution control system. By analyzing four pollution sources in X city, it was concluded that the water pollution control system based on this method could effectively improve the water pollution problem.

6. Conclusion

With the wasteful use of water resources in society, many water pollution problems have been caused, and the pollution of water resources has also been aggravated. The prevention and control of water pollution is to control the physical properties of the water body. The utilization of water resources has adverse effects on human health and ecological environment, thus resulting in the deterioration of water quality. With the deepening and extensive water pollution prevention and control projects, human beings have to pay more costs to solve these problems. At present, with the use of ant colony algorithm, the application research of water pollution prevention and control system has made progress, and the hydrological and ecological environment of the whole region has been optimized through relevant technologies.

Funding

This article is not supported by any foundation.

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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