Scholar Publishing Group
Water Pollution Prevention and Control Project
https://doi.org/10.38007/WPPCP.2020.010305
ISSN 2790-2730 Vol. 1, Issue 3: 39-49

Chaotic Particle Swarm Optimization in Water Pollution Control System Planning

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Keywords: Water Pollution, Pollution Control System, Chaotic Particle Swarm Algorithm, System Planning

Abstract: Rivers and lakes are an important part of the water environment and also an important part of social and economic development. However, rivers and lakes contain a large number of toxic and harmful substances, resulting in rapid deterioration of water quality. The planning of water pollution control system is based on optimization theory. By coordinating the relationship between the components of the water pollution control system, the pollution control cost of the whole water pollution control system is minimized, but it must meet the water quality requirements. The traditional methods to solve nonlinear problems include linear methods and nonlinear programming methods. However, traditional methods are not only complex, but also have strict mathematical requirements and tend to local extremes. It is often easy to fall into local extremum, and the result is unsatisfactory. Based on this, this paper first investigated the concept and content of water pollution control system planning, and discussed the classification and treatment of water pollution control system planning. Then, this paper put forward the method of sewage resource planning, and then used chaos particle swarm optimization algorithm to strengthen the construction of water pollution control system. Through comparison, it can be seen that the degree of pollution control after the new water pollution control system was 31.1% higher than that before the control, and the degree of resource protection was 31.5% higher than that before the control. After using the new water pollution control system, the wastewater treatment efficiency was 0.29 higher than that of the traditional monitoring system, and the system management efficiency was 0.26 higher than that of the traditional system.

1. Introduction

In order to reduce water pollution, rationally develop and utilize water resources, protect and improve the water environment, the state must invest heavily in the construction of sewage treatment plants to avoid the continuous deterioration of water quality. Within the treatment capacity of the reservoir, all components of the water pollution control system are coordinated to

achieve economic, social and environmental coordination, taking full account of the technical and other aspects of water quality. Satisfactory effect on water quality can be achieved by achieving water environment objectives. The best implementation scheme is found to solve the water pollution problem under pressure and meet the water quality requirements.

Water pollution control system has been widely used in water pollution. He Mingjing discussed the application of biochar in municipal wastewater treatment, industrial wastewater purification and rainwater management under the background of sustainable development [1]. Qi Ji believed that the mismatch between enterprises distorted the size distribution of enterprises in China, thus amplifying the industrial water pollution. The data at the enterprise level showed that large companies were more likely to use clean technology, but face higher distortions [2]. Sharma Rakesh K found that in today's global society, the development of new materials for wastewater treatment had aroused the interest of academic and industrial researchers, because it could ensure reliable access to clean water [3]. The main objective of Shafeeque Muhammad's research was to investigate the common benefits of COVID-19 blockade on the atmosphere and aquatic ecosystems under the restricted human activities in South Asia. He suggested that the use of fossil fuels should be judiciously restricted to control air and water pollution [4]. Ismail Muhammad believed that the water pollution caused by textile industry wastewater was causing serious human health problems. Water pollution caused by pathogenic bacteria, especially Escherichia coli and other microorganisms, was due to the mixture of fecal substances and drinking water, industrial and domestic sewage, pasture and agricultural runoff [5]. Ryabushko L I found that the existence of water quality indicators in the seabed community indicated that the organic substances were continuously flowing, and these organic substances were gradually utilized by the biological part of the coastal ecosystem [6]. The above studies have described the harm of water pollution, but there are still some deficiencies in the water pollution control system.

Many scholars have analyzed and studied the pollution control system. Li Z. H. O. U found that as part of the efforts to control water pollution, the local government of China introduced the river director system, and designated individuals were responsible for protecting specific watercourses. As one of the most prominent water pollution sources, agricultural non-point source pollution was becoming increasingly serious [7]. Martini Sri discussed the latest development of membrane technology for sewage and wastewater purification based on the mixed application of membrane technology with other types of water treatment methods such as adsorption, advanced oxidation process and biological activated sludge [8]. Li Xiang believed that to solve the increasingly serious water pollution problem, water resources, water environment and water ecology must be systematically managed as the elements of the basin. The comprehensive treatment of water pollution in the basin should take the basin as a whole, respect the natural laws of the river and lake system, and focus on protecting and repairing its natural ecological environment, so as to give full play to the comprehensive ecological service function of rivers and lakes [9]. Hanif M A's research aimed to assess the water pollution status of Kapotaksha River and its impact on human health and environment. This river water pollution was caused by some natural processes, such as floods, storms and natural biodegradation [10]. Wu Jianhua's purpose was to understand the relationship between different groundwater quality parameters, and track the source and influence factors of groundwater pollution through statistics and multivariate statistical technology [11]. Obinna Isiuku Beniah investigated the water pollution of heavy metals and organic pollutants, and summarized the source, impact and progress of aquatic phytoremediation [12]. Singh Nirala believed that with the reduction of the cost of renewable power and the increasing demand for converting water pollutants into benign or useful chemicals. Electrocatalytic treatment of polluted water was becoming a feasible remediation technology [13]. All the above studies have described the water pollution control system, but there are still some deficiencies in the study of water pollution.

In order to understand the specific development of the water pollution control system, this paper analyzed the risks existing in the work of the water pollution control system. The concept and content of water pollution control system planning have been studied to better deepen the reform of water pollution prevention and control. Compared with the current water pollution control system, it is more accurate to use chaos particle swarm optimization algorithm to strengthen the water pollution control system, which is conducive to building a more complete water pollution control system.

2. Concept and Content of Water Pollution Control System Planning

The planning of water pollution control system includes the study of pollution sources and the assessment of water quality status. However, according to the national or municipal requirements for the environmental quality of water operation, the maximum allowable discharge of pollutants in the water body is calculated according to the appropriate mathematical model, and the reduced pollution amount is calculated according to the estimated annual pollution load. The load reaches the planned level to make the water body operate according to the specified environmental quality standards. Its purpose is to evaluate various water quality control systems, and formulate plans that can be implemented by regulatory agencies to achieve the objectives of optimizing the planning of pollution source distribution, emission concentration, and emission path. The centralized assessment of the discharge of major pollutants and the discharge of urban and industrial wastewater into water has been optimized. The expected change of water pollution load is mainly due to the establishment of a practical water quality model and the calculation of the maximum allowable discharge of pollutants. Subsequently, the results are compared with the relevant standards.

Due to the complexity of practical problems, it is difficult to find the best solution. However, if properly managed, reasonable solutions and satisfactory results can be obtained within the framework of the best solution. Therefore, it is necessary to optimize the alternatives according to the actual situation and select the feasible ones, as shown in Figure 1. Facts have proved that the water pollution control system plan is a process of repeated coordination and decision-making, which is actually looking for the best solution [14].

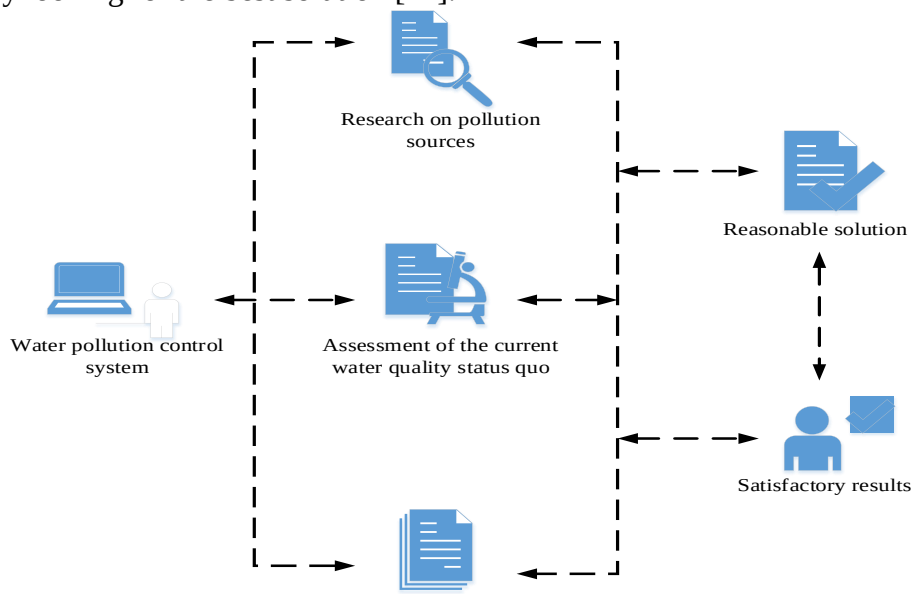


Figure 1. Concept and content of water pollution control system planning

2.1. Planning Objectives

The planning goal is the beginning and end of the planning work. The purpose of the planning has two parts: defining the problem and setting the goal. To clarify problems, it is necessary to study and analyze pollution sources, monitor water quality, understand water quality, determine the scope of planning work, and point out the direction and requirements of pollution control. Therefore, in today's society, it is necessary to propose different uses in different water bodies and river sections according to different economic and technical conditions to form targeted water body combinations.

2.2. Model Establishment

In order to facilitate the evaluation and selection of planning schemes, it is necessary to understand how different planning schemes affect the acceptability of water quality and how to improve water pollution, including the construction, validation of model structure, validation parameters, testing and application stages. The determination of the structure and parameters is an important step. In addition, in order to measure the pollution data and the concentration of pollution sources, an appropriate cost model must be established. In addition to water quality models, these models also provide an evaluation framework for modeling, comparison and optimization of various planning alternatives.

2.3. Simulation and Optimization

Optimization planning includes finding the cheapest management solution under water quality and technical constraints, including nonlinear mathematical planning and nonlinear iterative method. In addition to dynamic programming, these mathematical programming methods must also clearly record the objective functions and conditions. The purpose of optimizing plant design is to use the cost function. The optimization methods are usually dynamic programming, enhanced single method and enumeration method. Before planning the water pollution control system, different plans must be prepared for selection, and the advantages and disadvantages of the planning scheme must be evaluated according to the optimization modeling results, and the scheme closest to the optimization must be selected.

3. Classification and Treatment of Water Pollution Control System Planning

3.1. Planning of Water Pollution Control System

According to the different scope and content, the water resources management plan includes the national master plan and the basin plan, which are interrelated. The national master plan is the pioneer of other plans. This is a comprehensive and systematic plan and layout, which should be in line with the national reality and economic and technical indicators, and the overall plan should be clearly adjusted according to other planning levels. Basin planning refers to the water quality planning of the whole basin. In order to ensure that the water quality meets the standard without deterioration, the basin planning must formulate water quality indicators and pollutant emissions of all parts of the river, as well as reasonable construction planning for new wastewater treatment and expansion projects of the whole river.

Regional planning refers to regional water quality planning to solve the complex problems of urban and industrial pollution sources in the catchment area. It helps local governments find comprehensive water quality management solutions and provides financial information. The main

task of the sewage treatment plant planning is to review the existing sewage treatment plants in the catchment area. Considering economic factors, the most economical and cost-effective solution is selected to maintain and improve the operation parameters of the wastewater treatment plant. According to different solutions to the pollution problem, the planning of the water pollution control system is to deal with the optimal planning problem and the planning model optimization problem, which can be divided into three categories: export optimization, unified processing optimization and regional processing optimization, as shown in Figure 2.

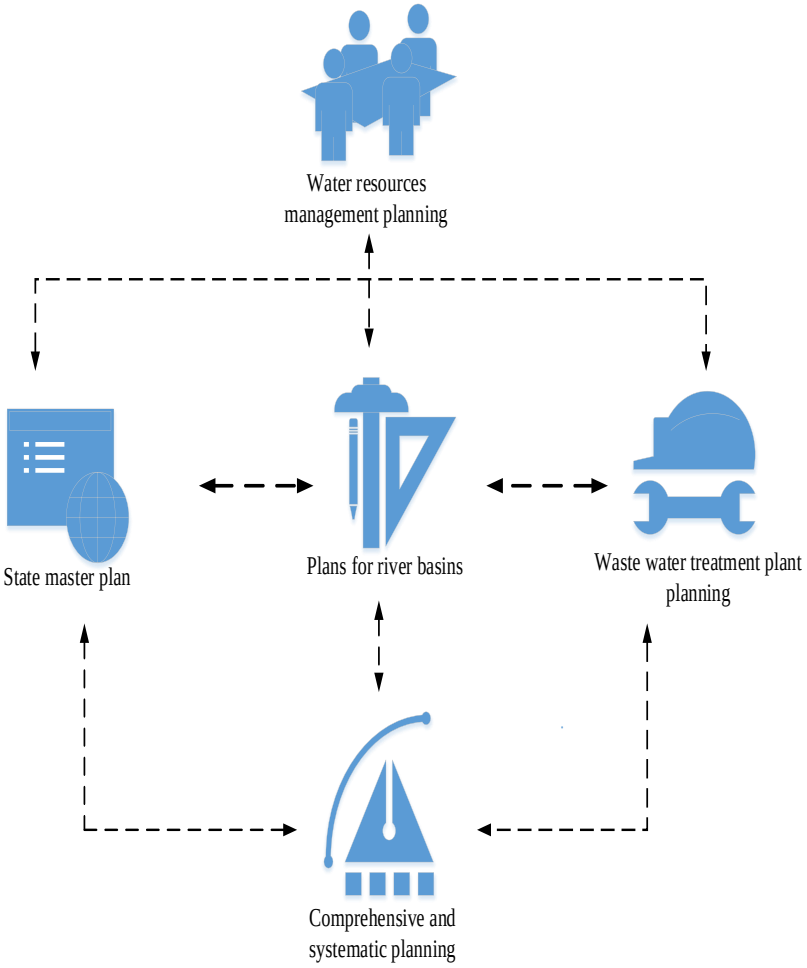


Figure 2. Planning of the water pollution control system

3.2. Optimization and Uniform Treatment of Discharge Outlet

This is the first problem studied in the design of water pollution system. Based on meeting the water quality requirements and the fixed size of each residential wastewater treatment plant, the water quality conditions are limited, the treatment efficiency of each wastewater treatment plant is optimized, and the cost of residential wastewater treatment is minimized. Different from the optimal wastewater treatment, the treatment efficiency of the planned regional wastewater treatment plant is the same. Therefore, the change in the treatment capacity and efficiency of the wastewater treatment plant and the reservoir itself is not considered, and only the possibility of joint treatment of urban wastewater is considered. The best combination of wastewater treatment costs can be achieved by studying the best combination of building address and treatment capacity in different regions, so as to minimize the total cost of the whole region, including wastewater transportation costs.

3.3. Regional Optimization

Considering the best construction site, the best capacity combination and the wastewater treatment efficiency, the regional optimal treatment problem has the advantages of the first two treatment problems. In other words, it is necessary to make reasonable use of the water purification capacity and make full use of the economic benefits of the sewage system, but there are no mature solutions to these problems. Therefore, under subjective conditions, the best planning method can be applied to obtain the ideal solution. However, in most cases, due to inappropriate conditions or special reasons, the best planning method cannot be used correctly, so scenario modeling method can be used.

The planning modeling method does not consider the connection between the wastewater treatment plant and the water body, and proposes different possible wastewater treatment plant systems according to the regional development and planning status. Then, the water quality model is used to simulate the relationship between wastewater discharge and water body, and check whether other options can be used. Finally, among the possible options, a relatively good one is selected. The quality of decision-making depends largely on the experience and skills of planners. In order to reduce this uncertainty, the application of this method should be proposed and take into account the preliminary plan as far as possible. In general, software modeling technology is more effective and practical and deserves full attention.

4. Planning Method of Sewage Recycling

In the treatment of water pollution, the concepts and principles of reuse and joint purification of internal water resources should be put into full use. Waste rivers and farmland should be fully utilized, and wastewater should be recycled and utilized scientifically [15]. Relevant departments should systematically study the typical water-saving technologies of industries and enterprises, and formulate local laws scientifically to remove and recover industrial wastewater to the maximum extent. In the daily life of the city, the relevant departments should study and analyze the urban water environment, and effectively cooperate with the sewage treatment plant to develop the urban wastewater toxicity reduction technology. Through the study of urban wastewater reuse methods, urban wastewater reuse planning is proposed. In agriculture, irrigation and micro-irrigation are needed to replace flood irrigation. It is necessary to accelerate the use of irrigation technology, reduce the waste caused by low evaporation efficiency of water resources, and improve research and utilization.

It is necessary to develop scientific and water-saving agricultural technology to achieve the highest level of water resources in agricultural production. The role of mass market supervision mechanism and macroeconomic management mechanism is emphasized. All sectors of society are mobilized to prevent and control water pollution and protect environmental production. The utilization efficiency of wastewater has been comprehensively improved. In infrastructure construction and other projects, the promotion of environmental protection should not only improve water protection, but also ensure water supply and economy. In order to realize the connection between society and environment, people need to do some research on the planning model. The management method is boldly tried and innovated. As for the control and management of water pollution, water quality objectives and environmental control measures are another step of the ecological control plan, which are of great significance to improve water quality and build ecological civilization, as shown in Figure 3.

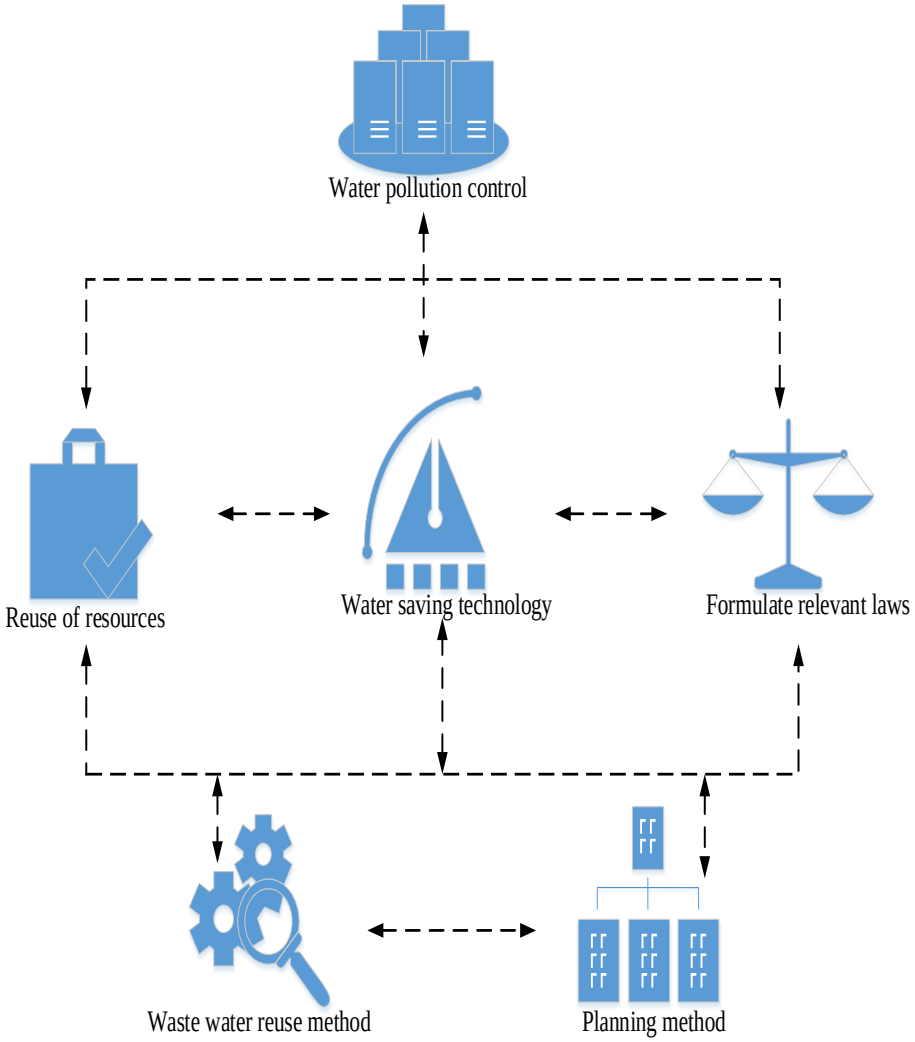


Figure 3. Planning method of sewage recycling resources

5. Construction of Water Pollution Control System Based on Chaos Particle Swarm Optimization

The particle swarm achieves the optimal solution by continuously updating the iteration. The particle velocity and position are updated as follows:

$$X_i^{(k+1)} = X_i^k + V_i^{(k+1)} \tag{1}$$

The optimization objective function of water pollution control system planning often uses the sewage treatment cost function. Therefore, the mathematical model of water pollution control system planning can be expressed as:

$$\min p = \sum_{j=1}^{n} C_j(\delta_j), 0 \le \delta_j \le 1 \tag{2}$$

$$Uk' + M = P' \tag{3}$$

The constraints are:

$$Vk'+N=C',K\geq 0 \tag{4}$$

6. Experimental Investigation Based on Chaotic Particle Swarm Optimization Algorithm

In order to study the specific application effect of the water pollution control system, this paper analyzed the pollution control degree and resource protection degree in the water pollution control system, and used chaos particle swarm optimization algorithm to build a new water pollution control system. Then, the pollution control degree and resource protection degree of the new water pollution control system were analyzed. First of all, this paper investigated the degree of pollution control and resource protection in water pollution prevention and control in three regions after the use of water pollution control systems, and compared them with the indicators of traditional water pollution control systems. The three regions were set as A, B and C. The specific investigation is shown in Table 1.

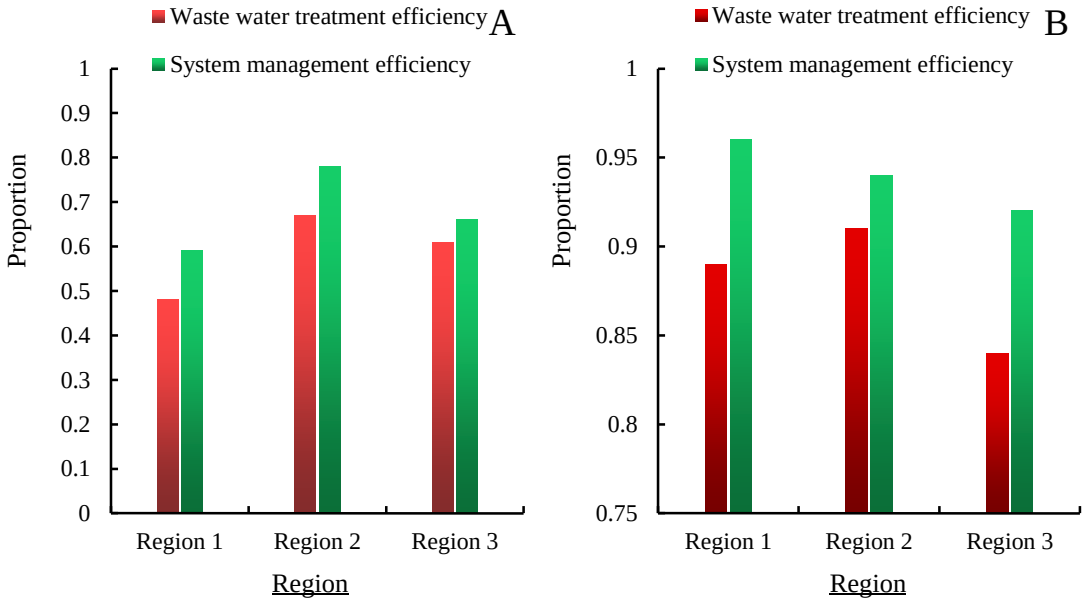
Table 1. The pollution control degree and resource protection degree of the traditional new water pollution control system

	Pollution control degree		Resource protection	
	Traditional control system	New control system	Traditional control system	New control system
A	54.6%	88.9%	56.5%	92.1%
B	61.4%	91.4%	48.3%	84.6%
C	58.3%	87.4%	67.4%	90.1%

According to the data in Table 1, under the traditional water pollution control system, the pollution control degree of A was 54.6%, and the resource protection degree was 88.9%. The pollution control degree of B was 61.4%, and the resource protection degree was 91.4%. The pollution control degree of C was 58.3%, and the resource protection degree was 87.4%. After using the new water pollution control system, the pollution control degree of A was 56.5%, and the resource protection degree was 82.1%. The pollution control degree of B was 48.3%, and the resource protection degree was 84.6%. The pollution control degree of C was 67.4%, and the resource protection degree was 90.1%. Under the traditional water pollution control system, the average pollution control degree was 58.1%, and the average resource protection degree was 89.2%. After using the new water pollution control system, the average pollution control degree was 57.4%, and the average resource protection degree was 88.9%. Through comparison, it can be seen that the degree of pollution control after the new water pollution control system was 31.1% higher than that before the control, and the degree of resource protection was 31.5% higher than that before the control.

Finally, chaos particle swarm optimization algorithm was used to analyze the wastewater treatment efficiency and system management efficiency of three regions after using traditional and

new water pollution control systems. The specific investigation results are shown in Figure 4.



A. Traditional water pollution control system

B. New type of water pollution control system

Figure 4. Waste water treatment efficiency and system management efficiency after the traditional and new water pollution control systems

Figure 4a shows the traditional water pollution control system, and Figure 4b shows the new water pollution control system. It can be seen from Figure 4a that after using the traditional water pollution control system, the wastewater treatment efficiency of area 1 was 0.48 and the system management efficiency was 0.59. The wastewater treatment efficiency of area 2 was 0.67, and the system management efficiency was 0.78. The wastewater treatment efficiency of area 3 was 0.61, and the system management efficiency was 0.66. It can be seen from Figure 4b that after the use of the new water pollution control system, the wastewater treatment efficiency of area 1 was 0.89, and the system management efficiency was 0.96. The wastewater treatment efficiency of area 2 was 0.91, and the system management efficiency was 0.94. The wastewater treatment efficiency of area 3 was 0.84, and the system management efficiency was 0.92. Through comparison, it can be seen that the wastewater treatment efficiency after using the new water pollution control system was 0.29 higher than that before the traditional monitoring system, and the system management efficiency was 0.26 higher than that of the traditional system.

7. Conclusion

The improvement of the awareness of water pollution needs a long process from inadequate treatment to final treatment and water pollution planning. Any change in this method is at the cost of water pollution and water shortage. Water pollution planning has never been developed from the legislative level. According to the urban socio-economic development plan and the urban master plan, environmental planning has become the three pillars of the overall regeneration of the city. With the deepening of the understanding of water crisis and the continuous development of computer technology and system engineering, new methods of water pollution planning are

maturing, and new and more complex methods appear, which also has a qualitative leap. It has played an increasingly important role in the development and rational use of water resources. Particle swarm optimization (PSO) is a new global optimization algorithm, which has the advantages of easy implementation, high accuracy and good stability, and shows great advantages in solving practical technical problems. However, the basic particle swarm optimization algorithm also has shortcomings such as slow convergence speed in the early and late stages, which needs various forms of improvement. Particle swarm optimization algorithm is based on particle swarm optimization and combined with chaos optimization algorithm to improve the local search efficiency of particle swarm optimization and avoid falling into local extremes. Through the excellent research performance of chaos particle swarm optimization algorithm, the application of chaos particle swarm optimization algorithm in water pollution control system planning was discussed.

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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