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Structure Design of Water Pollution Control System Based on Decision Tree Algorithm and Robust Optimization

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Abstract: In recent years, urbanization has been accompanied by the rapid development of population density and open space. People's attention and understanding of water pollution issues have gradually increased, and the infrastructure of water pollution control (hereinafter referred to as WPC) has also developed rapidly. However, the increasing pressure of the water supply system, the shortage of water resources, the increase of household pollutant emissions, the pollution of rainwater runoff and the continuous deterioration of water environment quality have made the design, construction and technical selection of the WPC system face serious challenges. The current situation of water environment lies in the lack of theoretical guidance and system structure for the design and construction of the existing WPC system. This shows that it is difficult to solve the complex problems caused by the diversification of water pollution system technology and functional objectives. Based on this, this paper first analyzed the problems faced by the WPC system, focusing on the fact that the WPC technology has not formed a complete method and theoretical framework, the lack of systematic analysis of the WPC infrastructure construction, and the lack of analysis and assurance of the planning scheme of the WPC system. Then, this paper proposed the construction and application of robust optimization model in WPC system, and discussed the basic framework of robust optimization model and standard control system design. After that, the improved decision tree algorithm and robust optimization were proposed to strengthen the construction of WPC system. Through comparison, it can be seen that the pollution source control strength of the new WPC system was 0.34 higher than that of the traditional WPC system, and the water quality monitoring accuracy was 0.37 higher than that of the traditional WPC system. The system perfection under the new WPC system was 39.2% higher than that of the traditional WPC system, and the cost control effect was 48.2% higher than that of the traditional WPC system.

1. Introduction

In recent years, environmental and health problems related to water pollution have become major obstacles to development. The characteristics of WPC are diverse structure, numerous objectives, numerous influencing factors and high uncertainty, which brings challenges to the reasonable and effective WPC. In this paper, the structure design and technology selection method of WPC system based on robust optimization is constructed. The structure design and technology selection method is established, and the water pollution technology database and modeling tool are developed to support the application of this method.

WPC system is widely used in water pollution. Shukla Bishnu Kant believed that groundwater was regarded as the most valuable and important prerequisite for human existence and survival, luxury and comfort [1]. Sheng Jichuan's research found that the obvious conflict between the requirements of ecological modernization and the use of power in China's water management system led to the distortion of local officials' behavior, which was an important source of problems in the water management system [2]. Li Z H O U determined whether the river length system effectively alleviated the pollution of new psychoactive substances, which was of great significance for achieving green development, and discussed the impact of the river length system on reducing agricultural pollution [3]. Ma Xiaojie found that the metal-organic framework was a new kind of porous inorganic-organic mixed crystal. Due to its competitive advantages compared with other traditional porous materials, it had very important application prospects in gas storage and separation, heterogeneous catalysis, sensing, drug release, environmental purification, water pollution prevention and control, etc. [4]. Liu Yi believed that the investigation of the relationship between water pollution and economic growth was an important part of the sustainable development of ecological environment and social economy. He combined the improved grey correlation model with the environmental Kuznets curve to quantitatively and qualitatively study the relationship between water pollution and economic growth [5]. Wang Yubao found that the government had established an environmental complaint reporting system for many years to monitor and manage industrial water pollution in a timely manner. Citizens could provide online and offline feedback on water pollution incidents and report human health risks [6]. All the above studies have described WPC, but there are still some deficiencies in the research of WPC system structure.

Many scholars have analyzed and studied the WPC system. He Mingjing discussed the application of biochar in municipal wastewater treatment, industrial wastewater purification and rainwater management in the context of sustainable development. Biochar made it more effective to target priority pollutants in industrial wastewater treatment through adsorption, precipitation, surface oxidation-reduction reaction and catalytic degradation process [7]. Kumar Vinod believed that water quality was a major issue of human concern because it was the most important natural resource. However, in rapidly developed countries such as India, uncontrolled growth in rural and urban areas was affecting water quality [8]. Li He, based on the quasi-natural experiment of the construction of the Yangtze River Economic Belt, adopted a difference model to test the impact of regional integration on cross-border pollution. The results showed that regional integration could significantly reduce transboundary water pollution [9]. Research by Rahman Mirza ATM found that heavy metal pollution in groundwater was a major environmental risk for Bangladesh. The water quality near the open space in the study area was relatively good. The area needed to be continuously monitored to check for further pollution distribution [10]. Pichura Vitalii believed that it was necessary to develop and comply with water-saving measures, use environment-friendly technologies and take adaptive protection measures in the case of uncontrolled increase of human impact and pollution intensity in the use of water resources [11]. The above studies all describe the

WPC system. However, there are still some deficiencies in decision tree algorithm and robust optimization.

In order to understand the specific development of the WPC system, this paper analyzed the risks in the problems faced by the WPC system. Robust optimization model was used to optimize the construction of WPC system, so as to better deepen the reform of WPC. Compared with the current WPC system, the WPC system constructed by improved decision tree algorithm and robust optimization is more perfect and can build a more complete control system.

2. Problems Faced by WPC System

2.1. Incomplete Method and Theoretical Framework of WPC Technology

In the process of WPC, the function of each subsystem in WPC is closely related to the technology used. In recent years, WPC technology has developed rapidly. The impact of technology operation and the number of information cost data, evaluation indicators and standards have increased significantly, and an appropriate and highly integrated technology system evaluation and selection tool has not been established. In short, there is a lack of evaluation methods for the basic concepts and characteristics of each subsystem, the interaction between each subsystem, and the technical optimization methods and tools appropriate to the system structure. The design and development of the WPC system is still immature. An effective method and theoretical framework can guide the structural planning and technical selection of WPC system [12].

2.2. Lack of Systematic Analysis of WPC Infrastructure Construction

There is always the problem of "top priority" in WPC [13-14]. Investment in WPC infrastructure is still mainly based on terminal control, which controls large-scale expansion of facilities. The non-point source wasteWPC technology and the rainwater discharge integrated pollution control system have been studied and applied, with the focus on improving the drainage quality standards and upgrading the technology of the main catchment areas. However, these technologies are still at an early stage. Infrastructure planning and technology selection have a long-term impact on water pollution indicators and water quality, because drainage and rainfall have a great impact on the life cycle of infrastructure. At the same time, the composition and structure of the WPC system become more and more complex. It is necessary to fully integrate the system construction and development and optimize the synergy between point pollution and non-point pollution to meet different natural resource needs and socio-economic development characteristics, as well as the regional WPC system, as shown in Figure 1.

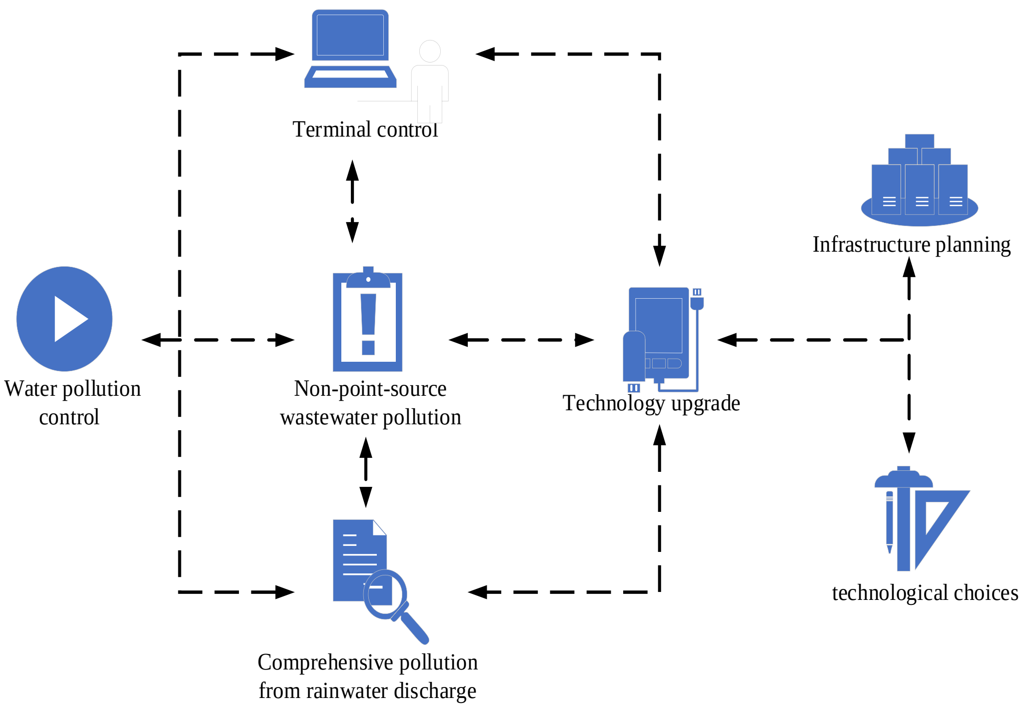


Figure 1. Lack of systematic analysis in the construction of WPC infrastructure

2.3. Lack of Analysis and Guarantee of WPC System Planning Scheme

There are still many uncertainties in the implementation and operation of the WPC plan. In an unstable environment, when the filtration process scheme is sensitive to the risk changes of the system structure and technical characteristics, the actual application of the program deviates from the optimization results. The effectiveness of the system for WPC often does not reach the expected effect, resulting in the water quality of the wastewater treatment plant not reaching the standard. The cost of the system far exceeds the budget, which leads to a significant reduction in the feasibility of the plan. Therefore, with the increasing demand for the stability and timeliness of uncertain WPC systems, these systems may be more and more affected by uncertainty to some extent. It is necessary to develop the method of system structure design and technology selection, and carry out collaborative optimization of nominal performance under uncertainty and robust performance under uncertainty.

3. Construction and Application of Robust Optimization Model in WPC System

3.1. Construction of Robust Optimization Model

In the robust optimization model, the combination of genetic algorithm and robust solutions creates a model structure for the structural design and technical selection of complex ecosystems in uncertain environments. With the deepening of system planning and decision-making research, and the increasing reliability of system performance in complex system decision-making, it provides better system performance and more reliable ability to cope with the constraints under various risks in the scenario of interference protection possibility of system operation under uncertainty. In the case of uncertain parameters of complex system, the interference of plan scheme and management strategy implementation is eliminated, and the robustness of overall system performance and program reliability are comprehensively evaluated. WPC planning options, compensation systems, and technical options for pollution control costs are provided. Then, the failure degree of several system parameters that lead to system performance degradation is statistically analyzed and estimated, and the impact of the uncertainty of model structure and technology on the overall performance of the system is quantified to further mark. It provides a set of avoidance values for decision-making and optimization options, and provides an optimization scheme that can still provide good performance when the system parameters are disturbed to a certain extent, as shown in Figure 2.

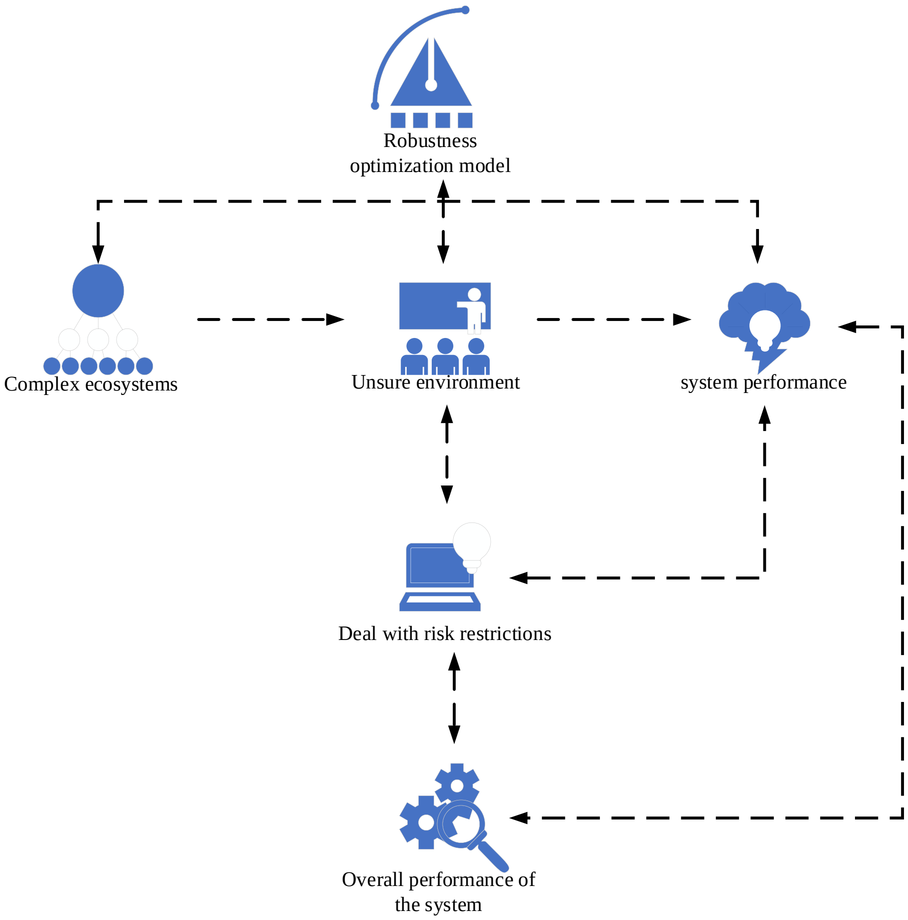


Figure 2. Robust optimization model construction

3.2 Basic Framework of Robust Optimization Model

The robust optimization design and technical inspection model of WPC system mainly consists of five parts: system promotion and structural planning, model input variables and parameters, mathematical model expression, model algorithm and model output. The system design is the basis of the whole module construction and application. On the basis of maximizing the authenticity and integrity of the internal connection of the system, the structure of the WPC system is summarized, and the WPC technology system is constructed. This includes sequencing the steps, making reasonable assumptions, simplifying the selection, scope and planning process of system model parameters, and finally creating a functional model.

Sustainable optimization input can be divided into two categories. First, the combined information generated by the water treatment technology database and the life cycle cost of process equipment are searched. Secondly, the economic and environmental characteristics are extracted. According to the basic data and model, the internal material flow of the system is evaluated, including basic information used to evaluate the potential use and use of recycled waste, as well as information about water quality. The model is analyzed to see whether it provides appropriate functional forms according to the system generalization and assumptions, and whether it establishes reasonable mathematical expressions for the objectives and boundaries of the WPC system. Based on the mathematical expression of the model, the appropriate calculation load solution model is used to develop the model algorithm, which can generate the structure plan and technical selection scheme for the WPC system.

3.3. Standard Control System Design

In different cases, the results of robust optimization are weighed between the system economy, environment and robustness performance. The stage of national socio-economic development and the level of infrastructure construction of water environment system under different interference levels and restrictions are comprehensively considered. The annual average domestic sewage volume and monthly average rainfall are used for model application and case analysis to formulate the standard of typical facilities. The water pollution technology database is used to apply the robust optimization model to the structural design and technical review of the standard WPC system. When calculating the material conversion process in the water treatment system, different monitoring data are needed to support the quantity and quality of information about domestic wastewater and rainwater flow.

Considering the difference between statistical data and monitoring data, the construction of typical feature information is based on statistical data on the one hand, and design criteria on the other. These standards can be used to analyze and discuss the process of optimizing the structure and technology combination, so as to provide technical policy recommendations for sustainable optimization of WPC system at the national level. However, special characteristic data must be used as input data for specific applications to monitor the quality and quantity of domestic sewage and rainwater, and correct model parameters, as shown in Figure 3.

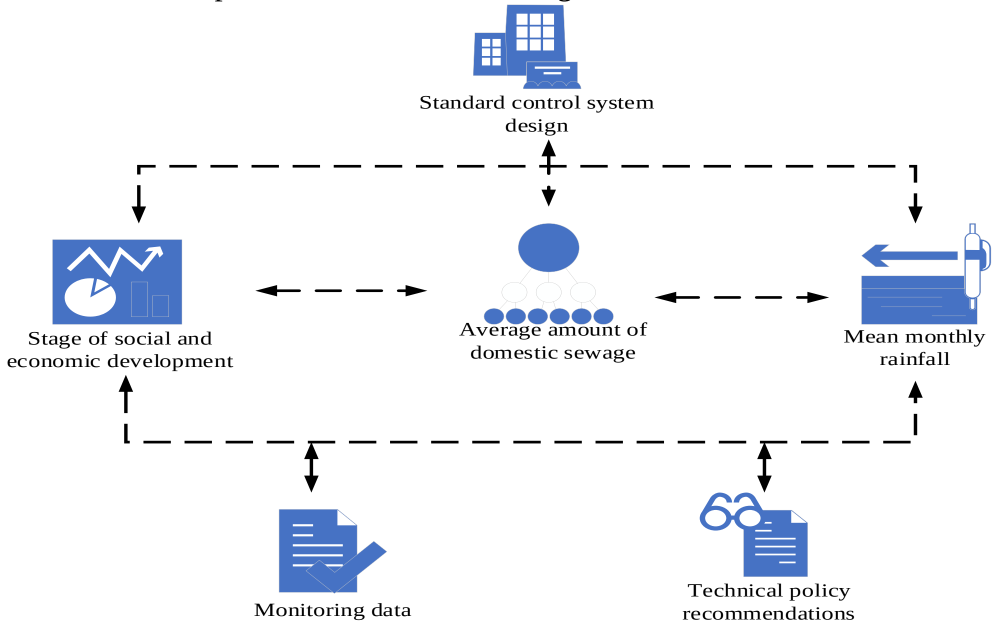


Figure 3. Standard control system design and model input

4. Application of Decision Tree Algorithm in WPC System

The improved decision tree algorithm is used to create a decision tree. First, the root node is classified. Assuming that each node is a root node, the entropy of node information is calculated. In the improved decision tree formula, the information entropy of each parameter can be calculated. After the report is calculated, a new node is selected to split the attribute value, and then the entire decision tree is created using repeated calculation.

It is supposed that a is a candidate attribute, and a has p attribute values. The corresponding probability is $t_1, t_2, ..., t_p$. a is expanded according to the principle of minimum information entropy. $\{b_1, b_2, ..., b_p\}$ is the attribute of p sub-nodes, and the corresponding information entropy is $T(b_1)$..., $T(b_p)$, then:

$$T'(a) = \sum_{i=1}^{p} t_i \cdot T(b_i) \tag{1}$$

The standard of a is:

$$a' = \min(T'(a)) \tag{2}$$

By introducing the algorithm into water quality evaluation, it can be obtained:

$$T'(a) = \sum_{i=1}^{p} (t_i + a) \cdot T(b_i) \tag{3}$$

5. Experimental Investigation Based on Decision Tree Algorithm and Robust Optimization Model

To study the specific effect of the improved robust optimization model on the WPC system, this paper analyzed the pollution source control strength and water quality monitoring accuracy of the traditional WPC system. Finally, the robust optimization model was compared and analyzed for the pollution source control strength and water quality monitoring accuracy of the improved WPC system. First of all, this paper investigated and analyzed the pollution source control strength and water quality monitoring accuracy of the improved WPC system by the robust optimization model in three regions, and compared it with the traditional WPC system. The three regions were set as A, B and C. Specific comparison is shown in Table 1.

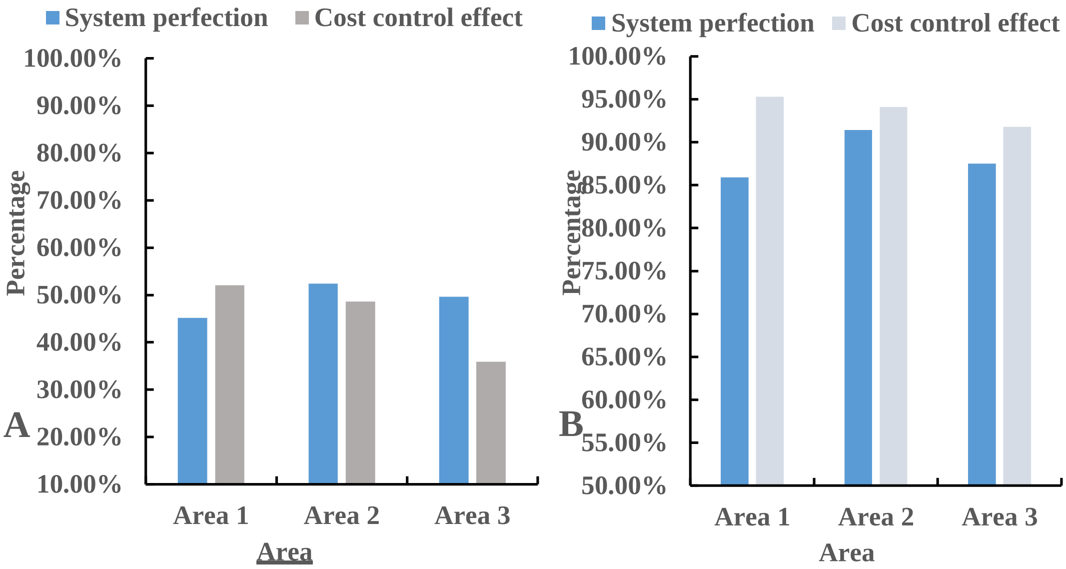
Table 1. Comparison of traditional and new WPC systems

	Pollution source control intensity		Precision of water quality monitoring	
	Traditional control system	New control system	Traditional control system	New control system
A	0.49	0.84	0.42	0.90
B	0.53	0.86	0.61	0.88
C	0.57	0.92	0.48	0.83

According to the data described in Table 1, under the traditional WPC system, the pollution source control strength of A was 0.49, and the water quality monitoring accuracy was 0.42. The pollution source control degree of B was 0.53, and the water quality monitoring accuracy was 0.61. The pollution source control degree of C was 0.57, and the water quality monitoring accuracy was

0.48. After the WPC system was improved by the robust optimization model, the pollution source control strength of A was 0.84, and the water quality monitoring accuracy was 0.90. The pollution source control degree of B was 0.86, and the water quality monitoring accuracy was 0.88. The pollution source control degree of C was 0.92, and the water quality monitoring accuracy was 0.83. On the whole, the pollution source control strength of the traditional WPC system was 0.53, and the water quality monitoring accuracy was 0.50. After the improvement of the WPC system in the robust optimization model, the pollution source control strength was 0.87, and the water quality monitoring accuracy was 0.87. Through comparison, it can be seen that the pollution source control strength of the new WPC system was 0.34 higher than that of the traditional WPC system, and the water quality monitoring accuracy was 0.37 higher than that of the traditional WPC system.

The WPC system can control and optimize the water pollution in the region. Under the continuous supervision of the government, not only the accuracy of water quality monitoring has been improved, but also the quality of water has been greatly improved. Then, the decision tree algorithm was used to analyze the system perfection and cost control effect of the improved WPC system in three regions in the robust optimization model. The specific investigation results are shown in Figure 4.



a. Effect of the traditional WPC system

b. Effect of the new WPC system

Figure 4. Effect of traditional and new WPC system

Figure 4a shows the effect of the traditional WPC system, and Figure 4b shows the effect of the new WPC system. According to Figure 4a, under the traditional WPC system, the system perfection of A was 45.2%, and the cost control effect was 52.1%. The system perfection of B was 52.4%, and the cost control effect was 48.6%. The system perfection of C was 49.6%, and the cost control effect was 35.9%. It can be seen from Figure 4b that under the new WPC system, the system perfection of A was 85.9%, and the cost control effect was 95.3%. The system perfection of B was 91.4%, and the cost control effect was 94.1%. The system perfection degree of C was 87.5%, and the cost control effect was 91.8%. On the whole, under the traditional WPC system, the system perfection was 49.1%, and the cost control effect was 45.5%. The system perfection of the new WPC system was 88.3%, and the cost control effect was 93.7%. The comparison shows that the system perfection under the new WPC system was 39.2% higher than that of the traditional WPC system, and the cost control effect was 48.2% higher than that of the traditional WPC system.

6. Conclusion

To sum up, within the framework of robustness analysis, a multi-attribute evaluation index system has been established to reduce the subjectivity of system optimization scheme selection. The best scheme combination has been evaluated and selected, which has improved the scientificity and quantification of scheme evaluation. Modeling tools were used to provide representative standard application analysis and provide multi-objective and multi-stage optimization options applicable to various risk limits and interferences. Through comprehensive evaluation and determination of system structure characteristics and robustness, it has provided decision basis and scientific support for system selection. By analyzing the characteristics of technology selection and the determination of key parameters, this study has provided quantitative baseline analysis for the development of WPC system and technology route selection, and has better understood the relationship between system structure and technology combination. The internal relationship between ecosystems, economy and system reliability have been analyzed. The parameters are moved in the model, which helps to determine the nature of cumulative and uncertain reactions.

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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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