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Exploration on the Relationship between Water Pollution Prevention and Control Based on Grey Correlation Analysis

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Abstract: The construction of ecological civilization is an important symbol of sustainable development. To establish and realize the concept of silver mountain and gold mountain is green mountain, it is necessary to develop civilization, enrich life and adhere to ecological health. With the development of industry, the acceleration of urbanization and the expansion of population, cities are facing a very serious environmental situation. Many rivers are often full of rotten food and unpleasant smell, and serious water pollution (WP) directly threatens the safety of drinking water and the living conditions of residents. The grey correlation analysis (GRA) method is a comprehensive evaluation method, which eliminates the influence of human factors and makes the evaluation results more objective and accurate. In this paper, the GRA method was used to study the methods of WP prevention and control. In this paper, the GRA method was used to evaluate water quality, and then the correlation degree of factors affecting WP was calculated. The WP comparison index was determined by selecting the reference index of “sewage to diameter ratio” acting on the WP system, and the grey correlation degree of each comparison index was calculated. In the experiment part, the effect of water quality evaluation was tested. The research showed that the GRA method had a good effect of water quality evaluation, and the accuracy rate reached 95%. Finally, according to the correlation degree of WP influencing factors, this paper put forward suggestions on WP prevention and control methods.

1. Introduction

Household, agricultural and industrial pollution is the main source of WP, but with the improvement of urbanization and industrialization, urban WP is increasing, and agricultural WP is also a serious problem. For example, pesticides, fertilizers and other substances used in urban agriculture have a significant impact on water eutrophication; The concentration of nitrogen and phosphorus compounds in water and the high content of organic substances that lead to algae growth may affect the oxygen content, resulting in the reduction of water transparency and deterioration of water quality. Therefore, the need to protect water resources and take effective action must be taken into account.

At present, many scholars have studied WP. Chen Zhao studied the consequences of recent WP control, which showed that this regulation reduced pollution intensive activities in highly regulated areas [1]. Pareek Ravi Kant studied the water quality of 16 stations in the upper and lower reaches of the town where the Gagar River crosses, and analyzed the possible pollution sources [2]. Akpomie Kovo G reviewed the use of natural banana peel for biological adsorption of pollutants in water, and discussed the factors controlling the removal of pollutants [3]. Lee Chang-Gu research showed that fixing effective titanium dioxide into polymers with affinity for specific priority pollutants can improve the efficiency of photocatalytic water treatment and reduce its energy demand [4]. Dwivedi Sanjay conducted an extensive review of the sources and levels of organic, inorganic and microbial pollution of the Ganges River, and data analysis showed that the Ganges River is seriously polluted [5].

Quesada Heloise Beatriz summarized the WP caused by these pollutants, and reviewed the recent literature on the use of low-cost adsorbents to remove major drugs from surface water [6]. Mekonnen Mesfin M estimated the global anthropogenic phosphorus load of freshwater and the related gray water footprint, and compared the gray water footprint of each basin with the runoff to assess the WP level related to phosphorus [7]. Li Jing measured the technological progress and its determinants based on input and output in 30 provinces and regions in China, and studied the water resources and WP emissions in the industrial sector [8]. Inman Alex studied the factors affecting WP mitigation in agricultural communities [9]. Ahmed Adeel investigated the risk perception of WP in Pakistani households and its potential impact on human health [10]. Although there are many researches on WP, with the development of industry, the situation of WP is becoming more and more serious. The issue about how to prevent and control WP is now a key problem to be solved.

In order to further improve the effect of WP prevention and control, this paper used the GRA method to study the WP prevention and control methods. This paper first introduced the prevention and control of WP, and then used the GRA method to calculate the correlation degree of water quality evaluation and the influencing factors of WP system. The experiment part detected and classified the groundwater quality, and compared the groundwater quality classification index with the actual classification results to verify the effectiveness of the GRA method for water quality evaluation. Finally, suggestions on WP prevention and control were put forward from three aspects: economy, water use efficiency and total water use.

2. Prevention and Control of Water Pollution

Prevention of WP is a management measure to protect and improve the environment. Water ecology is protected according to pollution problems or events, such as agricultural pollution that affects water ecology and drinking water safety. When carrying out WP prevention and control, it is necessary not only to manage pollution sources (including industrial enterprises) in an integrated manner, but also to build environmental management programs, including organizing and participating in WP prevention and control, and improving citizens' awareness of water conservation. The core is to achieve the principles of safety, cleanness and health in accordance with the principles of "water conservation, space balance, system control, and two hands" [11]. It is necessary to strengthen water resources management, water and soil coordination, river and sea coordination, and gradually realize the scientific management of basins, regions, lakes and oceans, so as to systematically promote the prevention and control of WP. The WP prevention and control plan is shown in Figure 1.

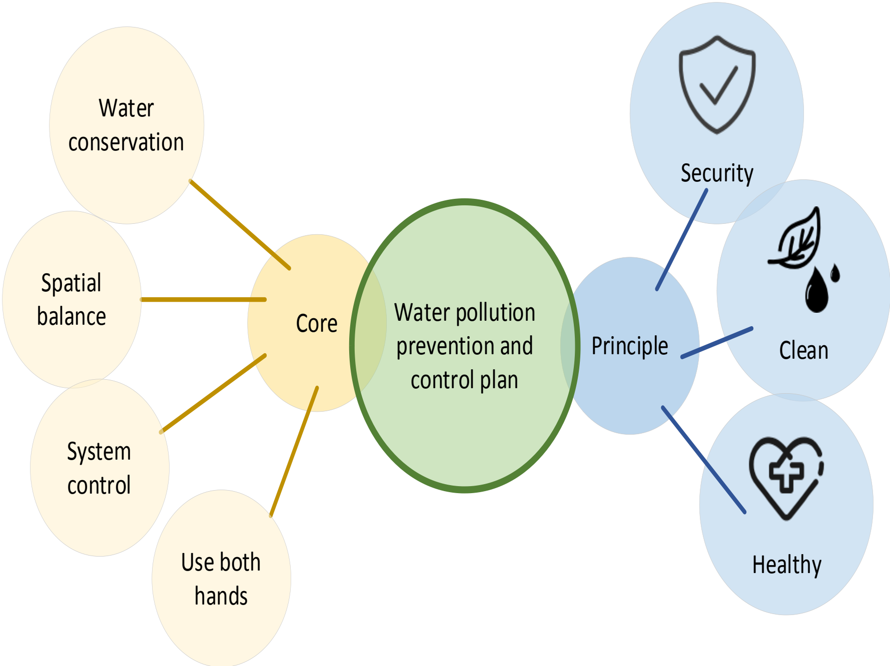


Figure 1. Water pollution prevention and control plan

3. Water Quality Evaluation Based on GRA

The grey system theory is mainly aimed at the research object of fuzzy system and incomplete information. It models the correlation analysis and target system, and discusses and understands the system using prediction and decision-making methods. Because of its low computational cost and consistent qualitative and quantitative analysis, it is widely used in many fields. If the change trend of subsystems or elements of two things is the same, the correlation between them is relatively large; vice versa. GRA provides quantitative evaluation of system development and modification for dynamic process analysis.

GRA is used to evaluate the WP situation of each area. The index value of the most polluted area in the study area is used as the reference point, and the area to be evaluated is used as the research object to calculate the correlation. The higher the correlation, the assessed area is similar to the area with the most serious pollution. Therefore, the order of the degree of correlation is the order of the degree of pollution.

It is assumed that the best value u_{0k} of each indicator is a unit in the order of number:

$$U_0 = (u_{01}, u_{02}. \dots, u_{0k}) \quad (1)$$

$$u_{0k} = \text{Optimum}(u_{0k}) \quad (2)$$

For the system composed of m-level units and n-level indicators, there are the following matrices:

$$U = (U_{ik})_{m\times n} = \begin{bmatrix} U_{11} & U_{12} & \cdots & U_{1n} \\ U_{21} & U_{22} & \cdots & U_{2n} \\ \vdots & \vdots & \ddots & \vdots \\ U_{m1} & U_{m2} & \cdots & U_{mn} \end{bmatrix} \tag{3}$$

The following link sequence is selected:

$$U_0 = (u_{01}, u_{02}, \ldots, u_{0n}) \tag{4}$$

In order to make each indicator comparable, the value of each indicator must be standardized. The standardization formula is:

$$X_{ik} = \frac{U_{ik} - \min U_{ik}}{\max U_{ik} - \min U_{ik}} \tag{5}$$

After standardization, the following conclusions are drawn:

$$X = (X_{ik})_{m\times n} = \begin{bmatrix} X_{11} & X_{12} & \cdots & X_{1n} \\ X_{21} & X_{22} & \cdots & X_{2n} \\ \vdots & \vdots & \ddots & \vdots \\ X_{m1} & X_{m2} & \cdots & X_{mn} \end{bmatrix} \tag{6}$$

Standardized sequence is used as reference sequence $X_0 = (x_{01}, x_{02}, \ldots, x_{0n})$ and comparison sequence $X_i = (x_{i1}, x_{i2}, \ldots, x_{in})$. The calculation formula of correlation coefficient is:

$$\varphi_{ik} = \frac{\min_i \min_k |x_{0k} - x_{ik}| + \sigma \max_i \max_k |x_{0k} - x_{ik}|}{|x_{0k} - x_{ik}| + \sigma \max_i \max_k |x_{0k} - x_{ik}|} \tag{7}$$

σ is the resolution factor, and $\sigma \in [0,1]$.

The following relationship matrix is obtained by using the formula for calculating the relationship:

$$E = (\varphi_{ik})_{m\times n} = \begin{bmatrix} \varphi_{11} & \varphi_{12} & \cdots & \varphi_{1n} \\ \varphi_{21} & \varphi_{22} & \cdots & \varphi_{2n} \\ \vdots & \vdots & \ddots & \vdots \\ \varphi_{m1} & \varphi_{m2} & \cdots & \varphi_{mn} \end{bmatrix} \tag{8}$$

The value of each indicator is different, and the correlation degree is calculated by multiplying the weight by the correlation coefficient.

$$Q = (q_1, q_2, \ldots, q_n) \tag{9}$$

$$\sum_{i=1}^{t} Q_k = 1 \tag{10}$$

t represents the number of indicators at this level. The formula for calculating the correlation degree is:

$$R = (r_i)_{1\times m} = (r_1, r_2, \ldots, r_m) = QE^T \tag{11}$$

4. Calculation of Correlation Degree of Influencing Factors of Water Pollution System

There are many unsafe factors to control WP. There are many kinds of WP. In addition to the common organic pollutants and other organic pollutants, there are many unknown pollution, such as heavy metal pollution. The exact reason for the high incidence rate of some WP areas has not been determined. The pollution sources are extensive and numerous, and it is difficult to enter the water body quickly. Due to the limited human and material resources, many wastewater discharge cannot be controlled, and many monitoring processes cannot be controlled online [12].

WP control is dynamic. In the heavy chemical stage, resource consumption and pollutant concentration would last for a long time. The transformation of WP from single pollution to comprehensive pollution and from general pollution to toxic and harmful pollution has led to the coexistence of point pollution and non-point pollution, the duplication of household pollution and industrial pollution, the new and old pollution and the cross secondary pollution. Therefore, the WP control system is a grey system with great uncertainty and can be subject to GRA [13].

Many factors affect the WP system. The "sewage to diameter ratio" is selected as the reference index of the WP system. The "sewage to diameter ratio" mainly refers to the ratio of sewage volume to runoff [14]. The comparison index is mainly selected from all aspects of the WP system, including socio-economic indicators, water-related indicators, environmental indicators and different levels of macro and micro indicators, and the indicators related to water consumption (WC) are included. The WP system indicators in this paper are shown in Table 1 to calculate the correlation between the comparison indicators and the WP system.

Table 1. Indicators of water pollution system

Type	Index
Reference indicators	Ratio of sewage to diameter
Comparative indicators	GDP
	Per capita water resources
	Total annual WC
	WC of 10000 yuan
	Unit discharge
	WC per 10000 yuan of industrial added value
	Reuse rate of industrial water
	Proportion of tertiary industry
	Per capita WC
	Popularity of water-saving appliances

The GRA method is used to calculate the grey correlation degree of each comparison index, as shown in Table 2.

Table 2. Grey correlation degree of each comparison index

Evaluating indicator	Relevance
GDP(Gross Domestic Product)	0.917
Reuse rate of industrial water	0.896
Total annual WC	0.892
Unit discharge	0.887
Proportion of tertiary industry	0.875
Per capita WC	0.871
Popularity of water-saving appliances	0.868
WC of 10000 yuan	0.862
Per capita WC	0.854
WC per 10000 yuan of industrial added value	0.852

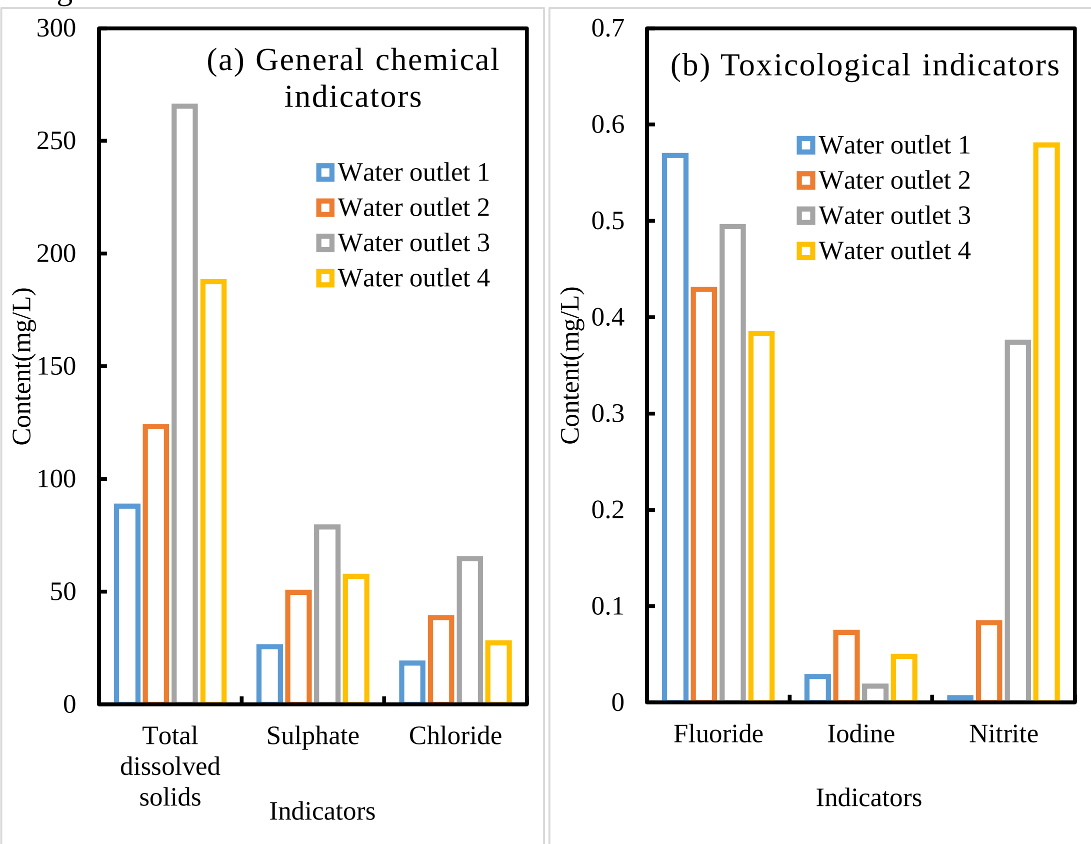
5. Application Examples of Water Pollution Prevention

The groundwater in a certain area was selected as the experimental object, and four outlets were selected to monitor the groundwater pollution in the area. The quality of the four outlets was classified according to the groundwater quality classification index, and compared with the actual outlet type. The groundwater quality classification indicators are shown in Figure 3.

Table 3. Groundwater quality classification index

Category	Index	I	II	III	IV	V
General chemical index Toxicological indicators Category	Total dissolved solids (mg/l)	≤300	≤500	≤1000	≤2000	>2000
	Sulfate (mg/l)	≤50	≤150	≤250	≤350	>350
	Chloride (mg/l)	≤50	≤150	≤250	≤350	>350
General chemical index	Fluoride (mg/l)	≤1.0	≤1.0	≤1.0	≤2.0	>2.0
	Iodine (mg/l)	≤0.04	≤0.04	≤0.08	≤0.50	>0.50
	Nitrite (mg/l)	≤0.01	≤0.10	≤1.00	≤4.80	>4.80

The groundwater in the two areas is monitored and classified, and the monitoring results are shown in Figure 2.



(a) General chemical indicators monitoring results for 4 outfalls

(b) Toxicological indicators monitoring results at 4 outfalls

Figure 2. Groundwater monitoring results

Figure 2 (a) shows the monitoring results of general chemical indicators of four water outlets, and Figure 2 (b) shows the monitoring results of toxicological indicators of four water outlets.

According to the monitoring results of the general chemical indicators of the four outlets, the total soluble solid content of the four outlets was 87.9mg/L, 123.4mg/L, 265.4mg/L and 187.6mg/L, all of which were below 500mg/L, meeting the Class II standard. The sulfate content of the four water outlets was 25.6 mg/L, 49.7 mg/L, 78.8 mg/L and 56.8 mg/L respectively, all of which were below 150 mg/L, meeting the Class II standard. The chloride content of the four outlets was 18.3mg/L, 38.5mg/L, 64.6mg/L and 27.3mg/L respectively; outlet 1, outlet 2 and outlet 4 were below 50mg/L, meeting Class I standard; the water outlet 3 was below 150mg/L, meeting the Class II standard.

For the toxicological index results of the four outlets, the fluoride content of the four outlets was 0.568mg/L, 0.429mg/L, 0.494mg/L and 0.383mg/L, respectively, which were below 1.0mg/L, meeting the Class I standard. The iodine content of the four outlets was 0.027mg/L, 0.073mg/L, 0.017mg/L and 0.048mg/L respectively; the water outlet 1 and 3 were below 0.04mg/L, meeting the Class I standard; water outlet 2 and 4 were below 0.08mg/L, meeting Class III standard. The nitrite content of the four outlets was 0.005mg/L, 0.083mg/L, 0.374mg/L and 0.579mg/L respectively; the water outlet 1 was below 0.01mg/L, meeting the Class I standard; water outlet 2 was below 0.10mg/L, meeting Class II standard; the water outlet 3 and 4 were below 1.00mg/L, meeting the Class III standard.

The four outlets were classified according to the monitoring results. Outlet 1 and outlet 3 were classified as Class II, and outlet 2 and outlet 4 were classified as Class III, which were consistent with the real classification results.

In order to more accurately verify the water quality evaluation of GRA method, this paper selected another 20 outlets from other outlets for water quality evaluation, and calculated the accuracy of the evaluation results. The evaluation results showed that the accuracy of the water quality evaluation was 95%, with high accuracy and good water quality evaluation ability.

6. Water Pollution Prevention and Control Suggestions Based on GRA

The correlation degree of factors affecting the WP system calculated according to the GRA provides a policy basis for effective control of the WP system.

6.1. Water Pollution Response Based on Fundamental Changes in Economic Growth

Among the above indicators, GDP has a high correlation with the WP system, indicating that the overall economy is closely related to the WP system. This strong correlation is unique in the accelerated stage of industrialization, not just "more developed and more polluted". Its fundamental importance is that if the economy grows rapidly, WP would increase with economic growth. Therefore, WP control at this stage cannot be realized simply. It is necessary to change the mode of economic development and improve the economic structure and productivity structure. In particular, it is necessary to speed up industrial restructuring and develop green and energy-intensive industries to reduce the unit cost of WP, which is the focus of WP control [15].

6.2. Water Pollution Control Focusing on Improving Water Use Efficiency

The second factor affecting the comparison index is the utilization rate of industrial water, which indicates that it is necessary to carefully study the impact of industrial water reuse on the WP system. It is not difficult to understand that the essence of industrial water reuse coefficient is industrial water efficiency. Industrial site pollution is a major component of WP. Reducing industrial wastewater discharge is crucial to control global WP management. The higher the water use efficiency per unit time, the less the industrial wastewater discharge, and the greater the impact on the water environment, thus achieving the WP target.

6.3. Control of Total Water Pollution and Reduction of Pollutant Discharge

Water use usually produces wastewater that affects natural water bodies and often pollutes water quality, but water saving can recover some wastewater. For example, waste water can be used to clean vegetables and toilets, thus reducing the use of clean water and WP. Although the reduction of WC may lead to the increase of pollution concentration, in the existing WC mode, wastewater can be reduced by reducing the total WC.

Emissions can be utilized. Therefore, using the existing potential of water conservation is an important and very realistic direction of efforts to reduce WP.

7. Conclusion

Prevention and control of water pollution is a century-old plan that cannot be solved at present. Water pollution control is a systematic project. All parties concerned should actively take subjective actions and take effective, practical and beneficial methods to move forward. In view of the current pollution situation, this paper used the GRA method to put forward the water quality evaluation method, and calculated the correlation degree of the influencing factors of the effluent pollution system. According to the correlation degree of the influencing factors, the water pollution prevention and control suggestions were put forward from the aspects of economic growth, water efficiency improvement and total water control. The experiment showed that the method has good water quality evaluation effect and can be applied to the field of water pollution prevention.

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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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