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Risk Analysis of Water Pollution Prevention Accidents Based on Improved Analytic Hierarchy Process

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Abstract: Water pollution has become more serious due to the rapid development of urbanisation and information technology in China and the rapid growth of the social economy. Water quality safety has become a major challenge in the world today and water pollution control is urgent. In recent years, urban groundwater contamination has been a frequent occurrence, and water safety has received key attention. Water quality assessment is an important task to ensure safe water for urban residents. Studying and assessing the risk of contamination at major water sources is key to solving major water pollution incidents. In this paper, the improved analytic hierarchy process is used to establish the risk assessment model of groundwater pollution (GWP) accidents, analyze the GWP situation in M city, and obtain that the risk of COD and ammonia nitrogen pollution in groundwater in M city has an increasing trend. In order to prevent and control water pollution in M City, suggestions on pollution source risk management and control and groundwater quality monitoring are put forward.

1. Introduction

As an effective way to prevent and control water pollution, urban wastewater treatment projects play an important role in urban construction and development, are closely related to urban and regional planning and development, and have a profound impact on the surrounding population and the development of the project site. Urban water pollution treatment is of increasing concern due to the ongoing urbanisation and the centralised construction and operation of wastewater treatment facilities.

In recent years, water pollutants have started to become complex and variable, and research into different pollutants has been included in the agenda. Some researchers have analysed the risk factors of emergency water pollution in China at this stage, determined the level of water pollution through emergency risk assessment and identified shortcomings in water pollution management efforts, and then simulated the results of hydrodynamic modelling of water pollution dispersion based on the establishment of relevant emergency planning indicators [1-2]. A risk assessment framework capable of predicting temporal and concentrated water pollutants in real time has been developed, and a risk assessment system has been established through a PSR model to identify water pollution risk sources and provide reasonable risk prevention and control measures to ensure that future risk management measures can be implemented consistently [3]. Although there are numerous research results on risk assessment of water pollution accidents, water pollution risk assessment is less studied in China and is not yet part of conventional environmental assessment, so further analytical work on water pollution risk assessment is needed.

This paper first introduces the concept of AHP, proposes an improved AHP method according to the shortcomings of AHP, and then analyzes the current situation of research on risk prevention of water pollution accidents. Then, taking the GWP in M City as an example, the GWP risk in M City is evaluated by analyzing the changes of PH value, COD and ammonia nitrogen in M City in 2017-2021, and finally, the countermeasures for the prevention and control of GWP in M City are proposed.

2. Basic Overview

2.1. Improved Analytic Hierarchy Process (AHP)

AHP is a hierarchical evaluation metric, where evaluation metrics are divided into target levels, decision levels, etc. By combining previous experience with the metric whose components are more important in a two-by-two comparison of different metrics, the importance of each metric can be assessed against predefined scoring criteria to generate a scoring matrix [4].AHP is a systematic, fast and practical analysis that requires relatively little quantitative data and which is very easy to collect. However, the lack of quantitative data and the overwhelming influence of human confounding factors make it less convincing, while data collection and weighting are more difficult when there are many indicators [5]. In addition, as AHP needs to be divided into nine allocation levels, the experience of decision makers is more stringent and the consistency testing process cannot be carried out smoothly. As a result, some scholars have increased the level of traditional AHP scoring, which has the advantage of being able to compare the importance of indicators more accurately and make the judgement matrix more mathematically sound. When it is not easy to define the importance of the assessment matrix, the AHP method is usually used, dividing the nine scales into three levels and reducing the influence of subjective outcome assessment [6-7]. The specific process is shown in Figure 1.

The advantages and disadvantages of improving AHP are as follows:

Advantages: designed according to a decomposition, matching and basic ranking process, with a strong systematic and clear logical thinking; adapted to decisions that lack quantitative data or have strong subjective preferences. Disadvantages: if there are too many indicators, the amount of data to be calculated and considered increases and the calculation process becomes more complex; only the best of the current calculation results can be selected and no new calculation options are available [8].

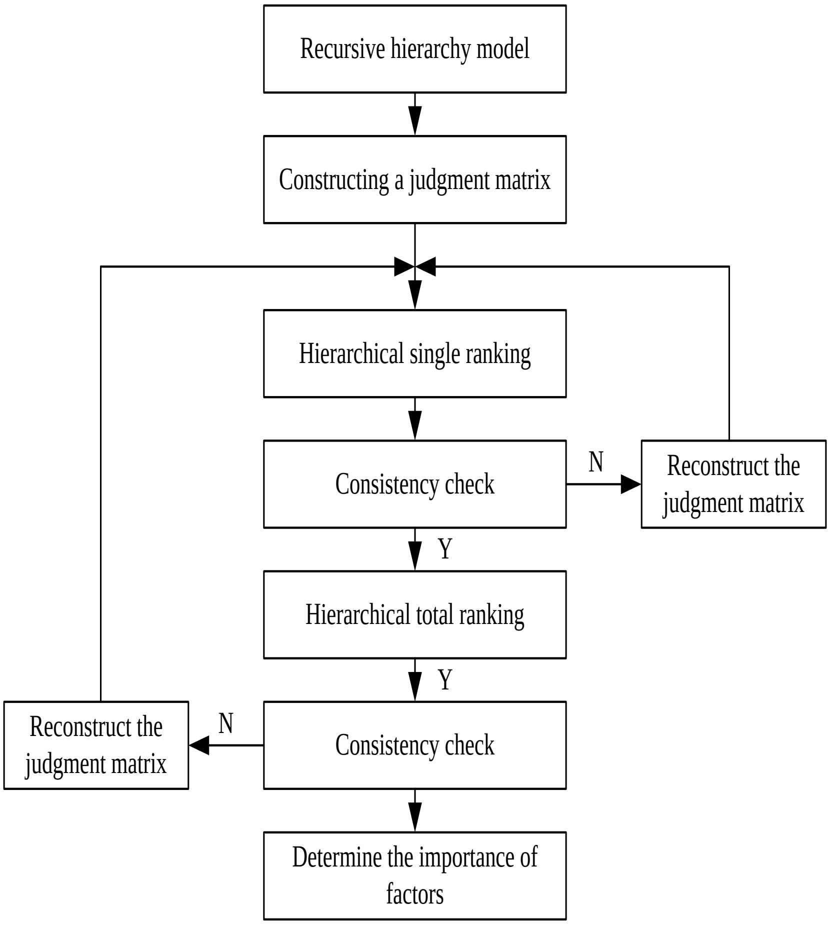

Figure 1. Improved AHP calculation process

2.2. Research on Risk Prevention of Water Pollution Accidents

Accidents are usually not accidental, there are factors beyond control in time and space that exist, but in reality they are a variety of cumulative and expanding safety hazards that ultimately exceed the limits of unavoidable outcomes, and accidents caused by water pollution fall into this category. In today's commercial society, various processes and technologies are man-made, and the results produced by manufacturing are not inevitable; these incomplete aspects will be the premise of an accident, and in theory any accident can be avoided and stopped [9]. Sudden water pollution accidents are a special type of accident, which are less predictable than ordinary accidents and have a high potential for disaster and secondary damage, so preventing water pollution can prevent not only accidents but also the spread of accidents. Risk prevention focuses on eliminating risk at an early stage, ensuring that effective preventive measures better reflect the value of prevention, identifying and responding to the main factors affecting risk, and improving the effectiveness of risk prevention [10-11].

3. Risk Analysis of GWP Accident in M City

3.1. Establishment of GWP Accident Risk Assessment Model Based on Improved AHP

The AHP first invites experts to give a comparison matrix for each level of judgement and then quantifies it through mathematical operations, which is extremely convincing in analysing complex problems with multiple objectives and indicators. The improved AHP is adopted to evaluate the GWP risk, and the evaluation expression of groundwater protection urgency is as follows:

$$k = (w_H, w_U)\begin{pmatrix} H \\ U \end{pmatrix} \tag{1}$$

Where, k is the evaluation result of groundwater protection urgency, H is the evaluation result of GWP susceptibility, U is the evaluation result of groundwater value function, and w_H and w_U are their weight values respectively.

Comprehensive evaluation of groundwater contamination risk:

$$K = (w_k, w_G)\begin{pmatrix} k \\ G \end{pmatrix} \tag{2}$$

$$I = C_i \cdot Co_i \tag{3}$$

Where, K is the GWP risk evaluation result, G is the pollution load level evaluation result, w_k and w_G are their weight values respectively, I is the pollution index, C_i is the measured level of the water pollutant and Co_i is the background value of the pollutant.

3.2. Evaluation of GWP Risk in M City

The groundwater of M city is sampled, and the sampling points are No. A, No. B and No. C. The trend of water quality change of these 3 sampling points during 2017-2021 is analyzed, and then the risk of water pollution accident in M city is evaluated.

Figure 2. pH change trend

The pH value is a basic indicator of the reaction of water quality conditions, which is related to the natural phenomena of aqueous solutions, chemical processes, both in terms of the content of heavy metals and evaluation of the toxicity of toxic substances. As shown in Figure 2, the variation pattern of pH value shows that the variation range of pH value of groundwater in M city from 2017 to 2021 is between 7.5-8.5, and the water quality is alkaline. The variation pattern along the range basically follows the principle of decreasing along the range.

Table 1. Trend of COD value (mg/L)

	2017	2018	2019	2020	2021
A	19.35	6.28	14.52	16.33	11.46
B	5.18	7.93	10.41	8.77	12.23
C	14.76	14.08	12.97	10.24	13.58

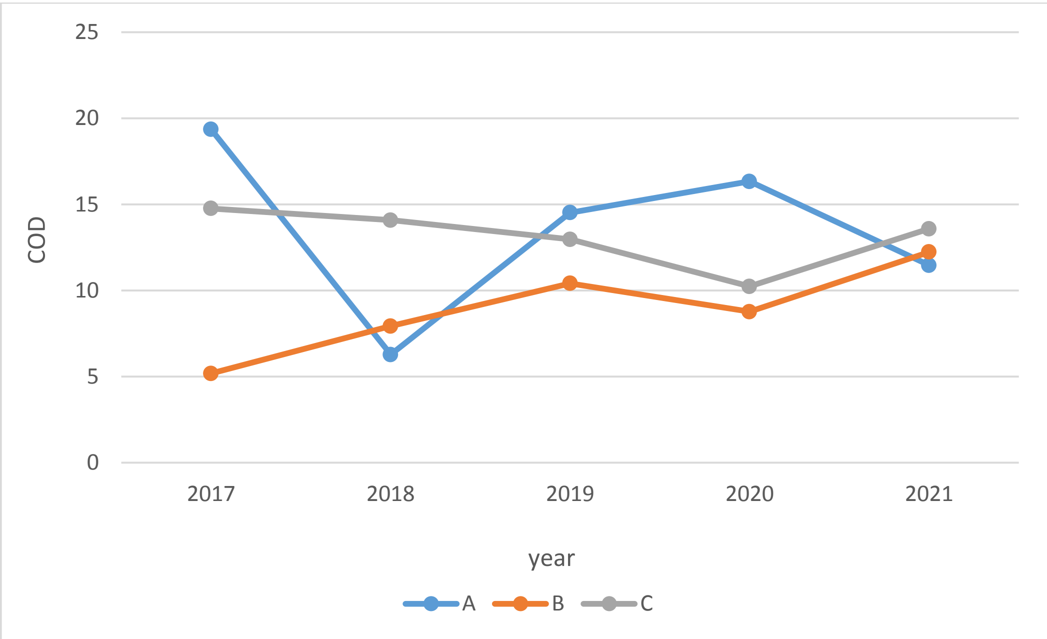

Figure 3. Change in COD pollution from 2017 to 2021

As shown in Table 1 and Figure 3, the trend of COD from 2017 to 2021 shows that its level changes between 5.0-20.0 mg/L. Except for sampling point A where COD exceeds 15.0 mg/L in 2017 and 2020, most of the monitored values are below 15.0 mg/L, which is lower than the limit value of Class I water in the surface water environmental quality standard, indicating that the COD content of groundwater in city M is low. And the changes of COD at sampling points B and C were relatively smooth. Some scholars have pointed out that the COD values of groundwater in M city are around 11.0-13.0 mg/L and the trend is smooth. This conclusion is comparable to that obtained in this paper. However, in 2021, there is an increasing trend of COD values in groundwater, which indicates that the risk of COD contamination of groundwater in M city may increase.

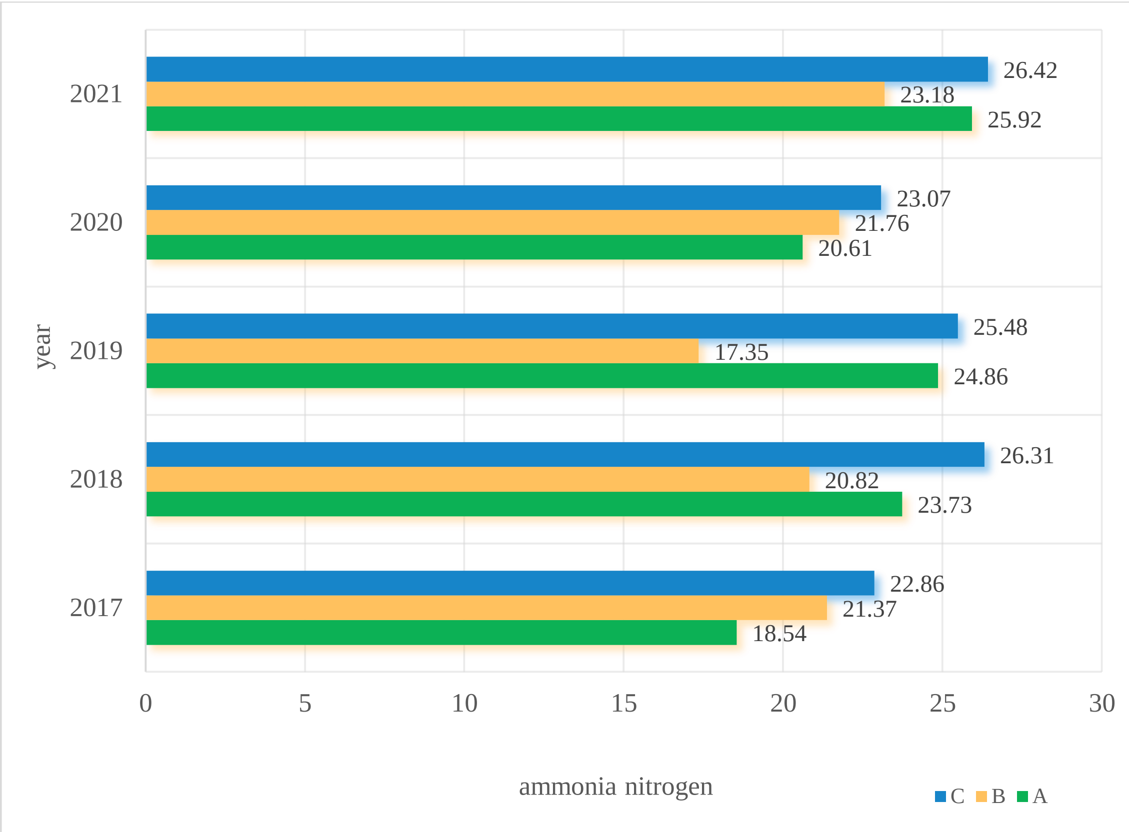

Figure 4. Trends of ammonia nitrogen (mg/L)

Ammonia nitrogen mainly comes from human and animal manure and petrochemical and metallurgical industries. According to the report, the main pollutants in the groundwater of city M contain high concentration of ammonia nitrogen in all years, which is mainly due to the discharge of domestic sewage and the discharge of chemical and metallurgical enterprises in city M. As the results in Figure 4 show, the variation of ammonia nitrogen in the groundwater of city M is not large. The results show that ammonia nitrogen has not changed much over the years, and the range of change is 17.0-27.0 mg/L. There are many important petrochemical enterprises in M city, and the population of M city is large, so the amount of domestic sewage discharge is large, and the daily treatment capacity of the sewage treatment plant is smaller than the discharge, which causes the increase of ammonia nitrogen content in groundwater in M city.

In summary, the overall variability of the temporal distribution of COD, ammonia nitrogen and pH in the groundwater of M city is large, without obvious regularity, and has the characteristic of great randomness. From the change trend of these three types of pollutants, COD pollution and ammonia nitrogen pollution have a rising trend, and these two pollutants cause a greater risk of water pollution to groundwater.

4. Water Pollution Prevention and Control Measures

4.1. Pollution Source Risk Control Measures

In view of the high risk of GWP accidents in M, strict measures should be taken to prevent the deterioration of GWP. The high-risk area is part of the main protection zone, where the discharge of toxic and hazardous wastewater and other wastes is prohibited; the use of highly toxic pesticides with large residues is prohibited; the dumping of wastewater in the bay is prohibited; and the exploitation of groundwater is prohibited. The acquisition and construction of the main sources of GWP are strictly controlled and GWP is closely investigated. Regarding existing sources of pollution, removal, relocation and cleaning of polluted sites need to be carried out [12].

Considering the level factor of production and processing equipment, the forced shutdown or relocation of high-temperature, high-pressure, high-risk enterprises means the elimination of obsolete and outdated production equipment. Targeting the effluent discharge factor, the city's sewage system should be completely revamped to improve the sewage network system in M and reduce sewage leakage. The government should increase funding for sewage control, speed up the construction of infrastructure in M city, improve the management system of enterprises and increase the capacity of sewage collection and treatment in M city; supervise and manage the river zone sewage authority; the difference between the permitted discharge rate and the excessive discharge rate is that the excessive discharge rate should be punitive, the more serious it is, the higher the rate [13-14]..

4.2. Improve Enterprise Risk Protection Policy Support to Ease Enterprise Resistance

As the most direct audience of the GWP prevention policy, the city of M has many industrial enterprises involved in urban pollution and strong opposition, so it needs to be given corresponding subsidies from other perspectives, such as incentive compensation policies. First, establish an incentive mechanism for industrial upgrading to promote the clean transformation of major polluting industries. Improve incentive mechanisms to promote the transformation and upgrading of major polluting enterprises, implement industrial clean production demonstration projects and promote industrial clean transformation [15]. Continue to deepen green credit services, with a focus on supporting industrial crop economies, clean water pollution and clean industry, and deepen green credit financial services for policy-oriented financial institutions. Secondly, compensate companies for closing and transferring operations in the form of subsidies in lieu of public compensation or subsidies to compensate companies for economic losses suffered and to reduce the resistance pressure on affected companies [16-17]. Third, accelerate the operation of the environmental pollution liability insurance system to transfer the risk of water pollution from companies.

4.3. Strengthen Groundwater Quality Monitoring

Most of the current water supply facilities in M are old, as is the water supply network. it is difficult to ensure that major water pollution incidents are detected and that the drinking water in M is safe. Therefore, there is a need to strengthen the monitoring of groundwater quality in and around M. The establishment of a complete and effective water quality monitoring network is very important for the people of M and its surrounding areas [18-19]. Therefore, in order to prevent groundwater pollution in M, it is necessary to strengthen the daily monitoring of groundwater quality. The relevant institutions in M need to build a complete water quality monitoring system for the current situation of groundwater pollution, establish an online automatic water quality monitoring network system as soon as possible, improve the monitoring ability of pollution sources, increase the number of inspections and supervision of the upper pools in M, and ensure the safety of human drinking water in M.

5. Conclusion

Urban GWP events have an impact on water quality safety, destabilize water ecology and endanger the health of urban residents. In this paper, based on the evaluation results of GWP risks in M, for the prevention and control of GWP in M, we should insist on the equal importance of pollution source supervision and groundwater environmental protection, implement a combination of independent management and supervision and management to supervise key pollution sources, and adopt GWP prevention and control measures that are prevention-oriented, protection-first and treatment-remediation-supplementary.

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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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