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Research Article

Optimization and Allocation Method of Regional Groundwater Pollution Investigation Based on Analytic Hierarchy Process Model

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In urban construction, various heavy metals and pollutants have become an important source of urban pollution, and groundwater has become its main pollution object. In order to investigate and analyze the water pollution in the main urban area of HeFei, this article firstly analyzes the whole process through the investigation of groundwater status and characteristics and simulates each step effectively using the analytic hierarchy process (AHP). Then, taking the nine districts of HeFei as the actual investigation site and research object, a systematic and comprehensive investigation and simulation of groundwater pollution in the HeFei area was carried out. The results showed that the weight of chemical pollution is 0.450, environmental factors 0.241, and domestic pollution 0.309 in the target layer of HeFei's main urban area, while the sample distribution weight of each unit was the highest in Baohe District and the lowest in Chaohu City. Finally, the countermeasures for regional water pollution are put forward.

1. Introduction

Groundwater is an indispensable natural water resource for human beings, and it is one of the most important and widely used water resources on Earth. In some rural areas, groundwater is indispensable drinking water for them. However, with the development of industry, the wastewater discharged from industry enters the groundwater, which makes its water quality no longer as good as before. In this case, if people use groundwater again, it will affect their health. Groundwater pollution is becoming more and more serious, which will endanger the ecological environment of nature and, in the long run, the Earth on which human beings depend will be affected, and finally, affect human life. By comparing the number of algae in the water of the Chaohu raw water treatment plant in Hefei in different seasons, it is found that the annual average total number of algae at different sampling points in different seasons at different times is different [1]. The current situation of water pollution in Dianchi Lake is analyzed, and it is found that there are many reasons for water pollution, including the internal reasons of Dianchi Lake itself and the external man-made reasons. On this basis, suggestions and countermeasures for improving water pollution in Dianchi Lake are put forward, and a series of scientific methods are used to predict the improvement of the water environment by introducing external water and changing the operation mode of the lake [2]. By analyzing the surface subsidence caused by underground coal mining and the serious rupture of bedrock channels [3], it is found that the aquatic ecosystem is polluted by the outflow of heavy metal particles such as iron, manganese, zinc, nickel, strontium, barium, and lithium. Very low dissolved oxygen is usually associated with groundwater upwelling through channel crevices. Aiming at the method of establishing water pollution monitoring stations along the river to control river pollution [4], this article first carefully selects the sampling points, then gives the mathematical expression of the problem and the effective algorithm to solve the problem, and finally gives the actual data for analysis. Starting from the relationship between the lake and its surrounding land, the most easily polluted aquatic animals of the lake are described [5]. Taking Khazar Lake as an example, the physical and inorganic chemical parameters of water samples from five different depths of nine sampling points are analyzed, and the water quality is determined. According to Karaguezel R' classification, Khazar Lake is identified as Grade I and Grade III water quality. The impact of human factors on the water quality in the Jarvac basin is analyzed. The surface flow and underground flow of the lake were measured, and the main factors affecting the water quality of the Jarvac River Basin were analyzed, which were mainly divided into domestic pollution, industrial pollution, and agricultural pollution [6]. According to the known point source pollution, the sampling points of surface water and groundwater were established for specific analysis. The sampling point method was used to investigate the use of agrochemicals and fertilizers in golf courses. Six drainage samples were taken from three golf courses, and high levels of imipramine and cimipraminewere detected, with the highest levels exceeding 8 and 3 gL-1, respectively [7]. Through the determination of the content of chromium (Cr) and other metal elements in the soil around an abandoned chromate chemical plant in Hangzhou, it was found that heavy metal particles seriously polluted the groundwater [8]. However, the surface water in the rivers near the abandoned chemical plant is not affected by heavy metal particles, so the concentration of metal particles in different places is different, and the degree of pollution to surface water is also different. Measurements of heavy metal particles in a lake in Nagpur, Maharashtra, India, revealed that the dissolved composition of heavy metal particles was above the range of unpolluted water [9]. Therefore, lead, iron, and zinc are more serious in water pollution. Through the calculation of the water index of each place, the water quality was classified, the heavy metal pollution of soil caused by industrial wastewater was determined, and the water quality model was established to simulate the water quality parameters of Tunggak River. The water quality model was tested using data collected by collecting and analyzing water and soil samples [10]. Using 8 points to investigate the water quality in different areas, it was found that the odor was obvious and the pollution was serious from No. 5 Bridge to No. 15 Bridge of the Yellow River, and the field investigation results were consistent with the micronucleus technology [11]. In total, 48 samples of domestic water sources from 12 communities in the eastern part of Obolo were tested for one year [12], and three pollution indexes, water quality index (WQI), heavy metal evaluation index (HEI), and heavy metal pollution index (HPI), were used to determine the pollution of the water body. The acidification rate of domestic water sources and related factors change with the season. Through the measurement of heavy metal particles in Asa, Agba, Unilorin, and Sobi (Moro) Earth dam water in the central north of Nigeria by atomic absorption spectrophotometry, the trace metal pollution in the surface water of Earth dam was evaluated by metal index (MPI) and metal pollution index. It is found that the total metal pollution of Pb and Cd is more than 6.0, so the water pollution is more serious by Pb and Cd [13]. Having carried out sampling, bacteriological, physical, and chemical tests on a number of wells in the vicinity of the Behesht-e Zahra cemetery in Tehran, Iran, the results of these tests were then compared with the distance from the bottom of the cemetery to the aquifer, the distance from the cemetery to the water point, the amount of rainfall at the site, the topography and hydrogeology at the site, and the type and structure to analyze the pollution potential of groundwater [14]. This article makes a concrete, effective, and reasonable investigation and analysis of groundwater pollution using the AHP [15]. Groundwater is easy to be polluted. GA, AHP, and FA are used to construct a combination statistical method, and factor analysis is carried out for 32 scenarios. Analytic hierarchy process and genetic algorithm score and weigh all scenes. The results of the study are important for groundwater vulnerability assessment and provide a new reference for groundwater pollution assessment in the future [16].

2. Field Investigation of Regional Groundwater

Regional groundwater field investigation regional groundwater field investigation is an effective way to obtain data and samples, which can more reflect the real situation. If you want to be close to the real situation, you have to carry out the practice, and you have to start to collect the data needed for experiments and research. It mainly includes the following: data preparation, equipment preparation, prior analysis, route determination, and sampling point layout. Preparation in advance is the most basic part of the whole survey, which mainly includes data preparation, equipment preparation, analysis of preparation in advance, determination of route, and layout of sampling points.

2.1. Preparation in Advance. Data preparation: it is mainly for the preparation before field investigation. Good advance data can save manpower cost and time cost. Advance data mainly refer to the investigation background needed in the whole investigation process. Therefore, advance data are the basis of the whole field investigation. Advance data mainly include the following: determination of route, geographical location of unit layer, temperature and rainfall of unit layer, and investigation and research report. The specific data of monographs, papers, and charts are divided into necessary data, unnecessary data, and auxiliary data.

Equipment preparation: the commonly used equipment for water quality detection includes geological compass, steel tape, and altimeter, and the most important equipment is small, fast drilling equipment.

Prior analysis: first of all, read the water quality report and other documents, analyze and judge the distribution characteristics and storage capacity of groundwater in the sampling area, understand and analyze the pollution sources of groundwater, understand and judge the way of groundwater pollution, and divide the groundwater system

Table 1: Indicators of groundwater in the affected area.

Target layer	Criterion layer	Index layer	Direction	Unit layer
Unit weight of regional groundwater pollution investigation	Chemical pollution	Contents of mercury, cadmium, lead, arsenic, and other elements	Inverse	Unit layers 1, 2, 3, . . ., N
		Organic pesticide content	Inverse	Unit layers 1, 2, 3, . . ., N
	Environmental factor	Lithology of main aquifer	Moderate	Unit layers 1, 2, 3, . . ., N
		The measure of area	Just	Unit layers 1, 2, 3, . . ., N
	Domestic pollution	Population	Inverse	Unit layers 1, 2, 3, . . ., N
		Domestic sewage	Inverse	Unit layers 1, 2, 3, . . ., N
		Domestic garbage	Inverse	Unit layers 1, 2, 3, . . ., N

in the investigation area into several or even more than ten investigation units.

Determine the layout of routes and sampling points. Find the map and other data in advance, determine the sampling route, and determine a route to save cost, time, manpower, and financial resources.

2.2. Using AHP to Determine the Number of Survey Points in the Unit. Three factors should be considered in the distribution of groundwater samples: chemical, industrial, and living factors.

Step 1. Select statistical indicators and establish an index system.

The selection of statistical indicators needs to consider its systematicness, comprehensiveness, and continuity; that is, there must be a certain logical relationship, comprehensiveness, and hierarchy between indicators. This analysis is divided into four levels: target layer, criterion layer, index layer, and unit level.

Target layer: it is the weight of the regional groundwater pollution investigation unit.

Standard layer: it is composed of chemical pollution, environmental factors, and life pollution.

Chemical pollution: chemical pollution will change the pH of the water body, change the living environment of groundwater organisms, and even some chemical pollutants are toxic, which will affect the ecosystem of groundwater, thus affecting the quality of groundwater.

Environmental factors: different environments have different groundwater-specific conditions.

Domestic pollution: if the garbage produced in life is not properly disposed of, it will pollute the quality of groundwater.

Index layer: the content of elements such as mercury, cadmium, lead and arsenic (E), organic pesticide content (G), lithology of main aquifer (H), area (M), population (R), domestic sewage (K), and domestic waste (L). These factors will have different effects on groundwater quality. The higher the content of mercury, cadmium, lead, and arsenic, the higher the content of organic pesticides, the more serious the pollution of groundwater. Unit layer: it is composed of unit layer 1 and unit layer 2. All layers are listed in Table 1.

"Direction" represents the extent to which pollution can be recovered. Unit layer N is different target requirements under different indicators, which is mainly manifested in the index coefficients of index layers under different first-level indicators and second-level indicators, which can fully reflect the composition of the next-level indicators of the index layer and comprehensively construct the comprehensive evaluation of the index layer.

Step 2. Compare the indicators in pairs and construct the judgment matrix.

When index a is more important than index B, it is assigned to 9; when index a is more important than index B, it is assigned to 7; when indicator a is more important than indicator B, it is assigned to 5. When indicator a is slightly more important than indicator B, it is assigned to 3; when index a is as important as index B, it is assigned to 1; when index a is less important than index B, 1/9 is allocated; when indicator a is stronger and less important than indicator B, allocate 1/7; when index a is less important than index B, it is assigned 1/5; when indicator a is slightly less important than indicator B, 1/3 is allocated.

The index importance assignment is shown in Table 2.

The judgment matrix A is constructed according to the index degree assignment table above.

Step 3. Calculate the weight of each index in the index layer

The row vectors of the judgment matrix are geometrically averaged and then normalized. Finally, the weight of each index and the eigenvector W are obtained. The geometric mean is normalized by multiplying each line of the judgment matrix by the nth power of each element.

Judgment matrix is

$$A = \begin{pmatrix} a_{11} & \cdots & a_{1n} \\ a21 & & a_{2n} \\ \vdots & & \vdots \\ a_{n1} & \cdots & a_{nn} \end{pmatrix}. \quad (1)$$

Table 2: Index importance assignment.

Importance	Assignment	Importance	Assignment
Extremely important	9	Extremely unimportant	1/9
Strongly important	7	Intensity does not matter	1/7
Important	5	Unimportance	1/5
A little more important	3	It does not matter a bit	1/3
Just as important	1		

We have

$$\prod a_{nn} = \begin{Bmatrix} a_{12} * a_{12} * a_{13} *, \ldots, a_{1n} \\ a_{22} * a_{22} * a_{23} *, \ldots, a_{2n} \\ \vdots \\ a_{n2} * a_{n2} * a_{23} *, \ldots, a_{nn} \end{Bmatrix} = \begin{Bmatrix} B_1 \\ B_2 \\ \vdots \\ B_n \end{Bmatrix}. \quad (2)$$

Every element to the nth power is

$$\sqrt[n]{B} = \begin{Bmatrix} \sqrt[n]{B1} \\ \sqrt[n]{B2} \\ \vdots \\ \sqrt[n]{Bn} \end{Bmatrix} = \overline{w_i}. \quad (3)$$

Moreover, W_i is defined as

$$W_i = \frac{\overline{W_i}}{\sum_{i=1}^{n} W_i},$$

$$w = \begin{Bmatrix} W_1 \\ W_2 \\ . \\ . \\ . \\ W_n \end{Bmatrix}. \quad (4)$$

In formula (4), it is more convenient and more accurate to calculate the correlation adjustment coefficient. It can reflect the application of the weight coefficient more objectively and fairly.

The geometric mean is normalized to get the weight.

Step 4. Conduct the consistency test.

In order to avoid the logical contradiction between indicators, it is necessary to test the consistency of judgment matrix A. The test first calculates the maximum eigenvalue of the judgment matrix λ Max; then C_i and C_r were calculated.

Matrix A judges the matrix of index w and weight of each index in the index layer:

$$\lambda_{\max} = \frac{1}{n} \sum_{i=1}^{n} \frac{(AW_i)}{W_i},$$

$$C_i = \frac{(\lambda \max - n)}{(n-1)}\Bigg), \quad (5)$$

$$C_r = \frac{C_i}{R_i},$$

where R_i is defined in Table 3.

Generally, when C_r is less than 0.1, the consistency test of the judgment matrix is considered to pass; otherwise, it will not be passed.

Step 5. Unit reselection priority method

According to the relatively important weight of each index, the impact of each index on groundwater pollution can be known, and the distribution weight of each unit can be determined. Combined with the total workload, the number of samples allocated by each unit can be calculated, and the results can be used.

To determine the number of measurement points in the unit, the following measures were taken:

(1) Regional control takes the groundwater as different samples collected in the upper, middle, and lower reaches. The characteristics of groundwater in different regions are different, and the collected index data are also different. Therefore, the targeted collection is adopted according to the information that can be provided by different regions. The upper reaches are sparsely populated, and two samples of lithology and area are mainly collected; in the areas with strong human activities in the middle and lower reaches, chemical pollution and domestic pollution control are the main control measures, and the samples with E, G, R, K, L, and other indicators are the main ones.

(2) : Conditional possibilitythe collectability, data contrast, background possibility, pollution index, and importance of water quality should be considered when collecting samples. In the process of collecting data, we should make use of the data prepared before.

(3) Field investigation: according to the design scheme of the survey, the effective means of transportation, sampling tools, and field topographic map are used to carry out the field survey. Field investigation is to collect the data and other effective information needed in the experiment and research, and then according to this information, it is combined with the specific steps of AHP for specific analysis.

Well flushing is an important part of sampling. There are certain pollutants in the monitoring well. These pollutants will affect the results of groundwater measurement. In order to ensure the authenticity and integrity of the collected information, well flushing will be carried out before sampling.

Table 3: Average random consistency index of orders 1–15.

n	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
R_i	0	0	0.58	0.90	1.12	1.24	1.32	1.41	1.46	1.49	1.52	1.54	1.56	1.58	1.59

Figure 1: Geographical location of HeFei's main urban area.

After completion of well flushing, samples can be taken. The principle of sample integrity should be followed when sampling, and false report, fabrication, and omission of data are not allowed.

3. Application Examples

AHP introduced in this article has been effectively used in the groundwater of HeFei. Now, taking the groundwater of various districts in the main city of HeFei as an example, the specific application of this method is introduced.

3.1. Selection of the Sample Collection Area. The main urban areas of HeFei were Changfeng County, Feidong County, Luyang District, Yaohai District, Shushan District, Baohe District, Feixi County, Chaohu City, and Lujiang County. The survey area is about 11,445 square kilometers. In total, 130 groups of chemical samples are planned to be arranged in this investigation. The structure of the groundwater distribution model in the main urban area of HeFei is shown in Figure 1.

The distribution structure of groundwater in HeFei's main city area is shown in Table 4.

The calculation of target level index weight because the target level includes too large a range, leading to the weight of the indicators of this level cannot be quantified, can only be given artificial weight, that is, only qualitative comparison, so the index scale method is used for valuation, and the subsequent process can be carried out after the indicators of the first level are weighted. The relative important weight values of the target layer can be obtained through the index scale are shown in Table 5.

$$W^T \geq \{0.21, 0.13, 0.202, 0.123, 0.101, 0.102, 0.122\}. \quad (6)$$

In Table 5, the weight coefficients of the first-class index and the second-class index are used to see their index relationship.

The judgment matrix of different regions in HeFei is shown in Table 6.

Table 4: Distribution structure of groundwater in HeFei's main city area.

Target level	Allocation weight of urban units in HeFei
Standard level	Chemical pollution, environmental factors, and domestic pollution
Indicator layer	Content of mercury, cadmium, lead, zinc, and other elements and content of organic pesticide, main lithology of aquiclude, area, population, domestic sewage, and domestic garbage
Unit level	Changfeng County, Feidong County, Luyang District, Yaohai District, Shushan District, Baohe District, Feixi County, Chaohu City, and Lujiang Count

Table 5: Weight of the target layer and indicator layer.

Target layer	Value	Indicator layer	Value
Chemical pollution	0.350	Chemical element content	0.210
		Organic pesticide content	0.130
Environmental factor	0.202	Aquifer lithology	0.202
Domestic pollution	0.448	Area	0.123
		Population	0.101
		Domestic sewage	0.102
		Domestic garbage	0.122

Table 6: The judgment matrix of different regions in HeFei.

Index	Changfeng	Feidong	Luyang	Yaohai	Shushan	Baohe	Feixi	Chaohu	Lujiang
Changfeng	1	3	5	3	1/3	1/7	9	1/9	5
Feidong	1/3	1	7	5	3	1/9	5	7	3
Luyang	1/5	1/7	1	3	1/3	5	3	1/7	9
Yaohai	1/3	1/5	1/3	1	3	7	5	9	3
Shushan	3	1/3	3	1/3	1	9	3	7	5
Baohe	7	9	1/5	1/7	1/9	1	5	3	1
Feixi	1/9	1/5	1/3	1/5	1/3	1/5	1	3	5
Chaohu	9	1/7	7	1/9	1/7	1/3	1/3	1	7
Lujiang	1/5	1/3	1/9	1/3	1/5	1	1/5	1/7	1

Table 7: Weight judgment matrix of the criteria layer and element layer.

Index	e (mg/L)	g (mg/L)	h/class	m (km^2)	r (ten thousand)	k (L)	l (kg)
Changfeng	0.23	0.09	0.15	0.07	0.06	0.12	0.09
Feidong	0.101	0.08	0.09	0.07	0.08	0.11	0.10
Luyang	0.08	0.102	0.11	0.09	0.13	0.09	0.15
Yaohai	0.17	0.11	0.08	0.14	0.12	0.08	0.21
Shushan	0.06	0.13	0.11	0.16	0.07	0.07	0.13
Baohe	0.07	0.08	0.12	0.10	0.13	0.14	0.09
Feixi	0.05	0.07	0.09	0.103	0.14	0.12	0.08
Chaohu	0.06	0.14	0.10	0.12	0.09	0.15	0.09
Lujiang	0.18	0.27	0.15	0.147	0.18	0.12	0.06

In Table 6, the pairwise comparison of the importance among the nine districts of HeFei's main city reflects the importance among different urban areas.

After matrix operation, the maximum characteristic root vector is (0.23, 0.101, 0.08, 0.17, 0.06, 0.07, 0.05, 0.06, 0.18) to find $CR = 0.021$, so the matrix passes the consistency test. Similarly, the characteristic root vector of other indexes can be calculated, and the weight judgment matrix of the criterion layer element layer can be obtained in Table 7.

Finally, the total weights of each region are distributed as a whole, as shown in Figure 2.

The sampling quantity in the main urban area of HeFei is shown in Figure 3.

In Figure 3, the number of samples in the main urban area of HeFei is explained. The sample size is studied in this article, and the number is relatively sufficient. Therefore, the number and range of samples used in this article can fully reflect the application requirements in this article.

The regional density of HeFei sampling is shown in Figure 4.

4. Consequences of Regional Water Pollution

Groundwater pollution will lead to a decrease in soil quality, thus affecting crops, affecting the activity of underground organisms, resulting in changes in the biological system, and

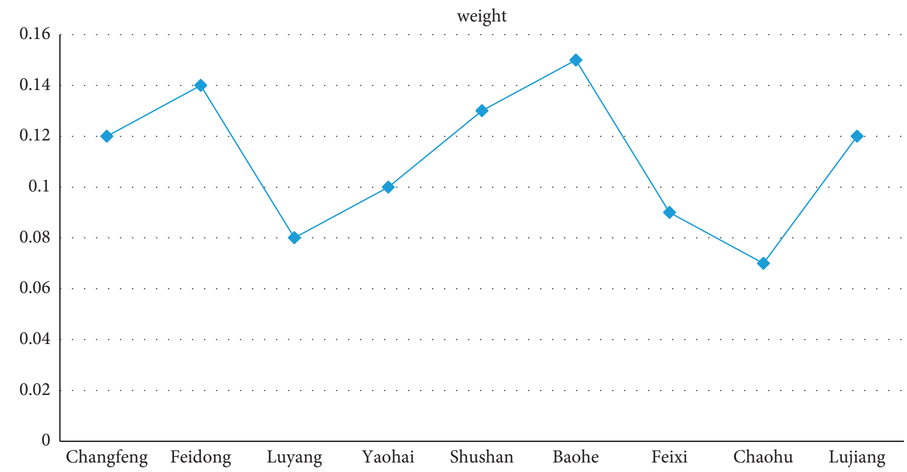

Figure 2: Regional total weight distribution.

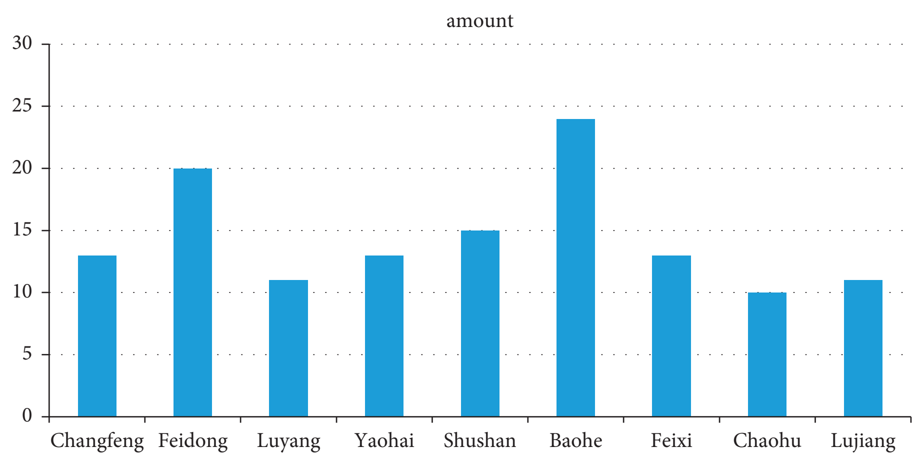

Figure 3: Number of regional samples.

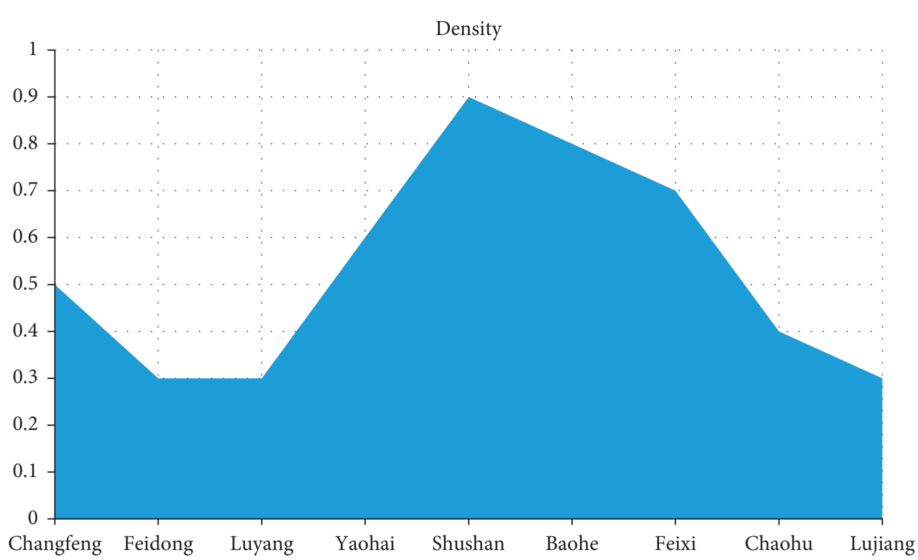

Figure 4: Regional density.

most importantly, affecting human health, resulting in a series of diseases. Thus, the quality of the soil is affected. After the groundwater is polluted, the pollutants in the water penetrate the soil and the soil is also polluted, resulting in a significant decrease in grain output. Every year, due to soil pollution, China's grain output decreases by an unlimited number, resulting in heavy losses for the country. The GDP of the country and the governments in various regions decreases to varying degrees, affecting the biological system in groundwater. Long-term pollution of groundwater will cause changes in the pH value of water. As a result, the acidity of water will increase, which will directly affect the living environment of aquatic organisms, affect their activities, and even cause their extinction. At the same time, a large number of bacteria will be produced in the polluted underground water, thus affecting the original biological system. Affected by class, after the groundwater is polluted, there are some carcinogens in the water.

Groundwater pollution will affect human health, so it is very important to control and prevent groundwater pollution. The prevention and control of groundwater should increase the investment in capital and manpower, and continue to carry out relevant research, so as to find more effective treatment methods, and avoid increasing from the source, discovery, protection, and water pollution in other areas.

4.1. Reducing the Generation and Discharge of Pollutants from the Source. Controlling pollutants from the source is the most effective way to prevent groundwater from being polluted. Before enterprises discharge sewage and waste gas, they should be treated to meet the standards before discharging. At present, China attaches great importance to groundwater pollution and other environmental pollution and has actively taken measures to solve this problem.

4.2. Strengthening Underground Water Testing. The pollutant detection equipment mainly includes acid detector, water pollution detector, and dynamic detector, which regularly detects the quality of underground water, analyzes and judges whether each indicator exceeds the standard, and records each detection.

4.3. Strengthening Publicity and Education. Recognize the vital importance of underground water to human life, let the masses supervise each other, reduce the harm of domestic pollution factors to underground water, and minimize the pollution of underground water. Promote the dissemination of knowledge related to the protection of underground water and improve the influence of education policies through the use of big data and information technology.

4.4. Optimization of Water Pollution Prevention and Control Technology. Improve science and technology and optimize filtration and separation technology so that groundwater has the opportunity to play a new role. Filtration and separation technology can be used for membrane filtration, primary filtration, microfiltration, and particle filtration, and separation operations are carried out according to different pollution levels and different filtration requirements. The polluted groundwater can be effectively purified, and then the polluted groundwater can be reused for the benefit of humankind.

4.5. The Government Has Taken Measures. In the face of serious underground water pollution and serious harm of underground water, governments at all levels should take corresponding measures to control and prevent underground water pollution. They should recognize the seriousness of underground water pollution and take measures in a timely manner so that the underground water pollution will be effectively controlled and will not continue to bring harm to human life.

5. Conclusion

In this article, the present situation of groundwater is analyzed from the degree and area of groundwater pollution and sustainability, and the characteristics of groundwater are analyzed from the aspects of concealment and irreversibility. Then, the relative importance of each index calculated by the AHP, combined with the total amount of work, determines the number of samples that each unit should take, followed by an on-site investigation, and then analyzes the harm of underground water pollution from the aspects of soil properties, human life, and ecosystem. Finally, reasonable suggestions are put forward to solve the underground water pollution, including reducing the generation and discharge of pollutants from the source, strengthening the underground water detection, strengthening publicity and education, optimizing the water pollution prevention and control technology, and taking measures by the government. After further research work, considering more pollution sources in the main urban area of HeFei, an AHP analysis is carried out, and other methods are comprehensively analyzed to compare whether there is a similarity in the results. At present, there are still some difficulties in obtaining the number of pollution sources, and there are many problems in data sampling and analysis. Finally, the collaboration between relevant parts is important to solving data problems together, and data processing and analysis methods should be better adopted for application.

Data Availability

The experimental data used to support the findings of this study are available from the author upon request.

Conflicts of Interest

The author declares that they have no conflicts of interest regarding this work.

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