Research on calculation and optimal allocation of groundwater resources in Rizhao coastal area

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Abstract. In this paper, the calculation and optimization of groundwater resources in Rizhao coastal area are realized by means of ground investigation, geophysical prospecting, pumping test, water level measurement and sampling test, groundwater recharge, diameter, drainage and other factors. According to the calculation and analysis of groundwater resources in the investigation area, the hydrochemical types in the investigation area can be divided into eight categories: Cl, HCO₃, HCO₃·Cl, HCO₃·SO₄, HCO₃·NO₃, NO₃·Cl, SO₄, and NO₃. The mineralization degree is mostly above 0.3g/l. The groundwater recharge in the investigation area is 8638.40×10⁴m³/a, and the groundwater consumption is 6017.12×10⁴m³/a. Furthermore, on the basis of calculation and analysis of groundwater resources, this paper delimits the prohibition and restriction zones of the investigation area by groundwater resources exploitation and hydrochemical properties, and puts forward reasonable exploitation opinions, such as building underground seepage interception dams and constructing groundwater reservoirs, so as to realize the optimization of groundwater resources in the investigation area. This not only guarantees the groundwater resources demand of Rizhao City, but also has certain reference and application value for the rational utilization evaluation of groundwater resources in other regions.

1. Introduction

To realize comprehensive planning, rational development and effective utilization of groundwater resources, groundwater resource evaluation which is a process of comprehensive analysis and optimization is proposed in this paper [1-3]. Decision of the CPC Central Committee and the State Council on accelerating the reform and development of water conservancy [4] and opinions of the State Council on implementing the strictest water resource management system [5] clearly require strict protection and management of groundwater. Rizhao, as a national Shandong peninsula city group and an important city in the blue economic zone, is known as the Capital of Water Sports and Oriental Sun City [6]. In recent years, the demand for water resources is increasing day by day with the rapid economic development, which makes the contradiction between the supply and demand of groundwater resources in the coastal areas of Rizhao more prominent and has become one of the important factors restricting economic construction and social development [7]. At the same time, over-exploitation and utilization of groundwater leads to regional over-exploitation, which brings a series of ecological and environmental problems, such as continuous decrease of groundwater level, deterioration of water quality and seawater intrusion, which endanger water supply security, food security, ecological security and seriously restrict sustainable economic and social development [8]. Therefore, the research on calculation and optimization allocation of groundwater resources in the coastal areas of Rizhao city is of great importance to the security of the local people and the rapid...
development of regional economy. It is of great practical and long-term strategic significance to guarantee the benign circulation of groundwater resources and water ecosystem and realize the rational, feasible and sustainable utilization of groundwater resources.

2. Investigation area overview

2.1. Geographical location
The investigation area is located in Rizhao, reaching the border with Qingdao in the north, Jiangsu province in the south, the coastline of the yellow sea in the east, and the red line of the restricted mining area in the west. Extreme geographic coordinates of the investigation area which is shown in figure 1 are 119°15'38"-119°38'50" E and 35°05'00"-35°35'58" N, with an area of 756km².

![Figure 1. Geographic location map](image)

2.2. Hydrological information
Due to its unique geological structure, Rizhao coast has formed a hydrologic pattern with mountain stream river as the main surface, few natural lakes and more artificial reservoirs. The rivers in the area belong to the system of sole inflow into seawater, and the river flows into the sea alone. The terrain has a large gradient and the source is short and the flow is short. The main rivers are Xiucheng river, Longwang river, Jufeng river, Futuan river and Liangcheng river, etc., as shown in table 1.

| The name of the river | Primary source                  | The basin area (km²) | General annual base flow (10km³) | Length of the trunk (km) | Estuary position                                      |
|----------------------|---------------------------------|----------------------|-------------------------------|--------------------------|------------------------------------------------------|
| Liangcheng river     | Jixian mountain, Wulian county  | 516                  | 14800                         | 42.7                     | Two towns make up the east of the village             |
| FuTuan river         | Damaan mountain, Wulian county  | 1060                 | 33500                         | 51.5                     | Kuishan street jiaokang southeast                     |
| Jufeng river         | Jiazi mountain, upstream of jufeng reservoir | 262                  | 11000                         | 30.7                     | Tao luzhen hou village east                           |
| Longwang river       | Youergu mountain                | 90                   | 3300                          | 17.2                     | Hushan town east lake village south                   |
| Xiuzhen river        | Sanhuang mountain, junan county | 412                  | 8462                          | 46.0                     | Lanshan danshui village east                         |

3. Data collection of groundwater resources
On the basis of making full use of the hydrogeological data in the early stage, this paper is carried out
by means of surface survey, geophysical exploration, pumping test, water level survey and sampling test.

(1) Data collection. Basic data of mineral resources, earthquake, water conservancy, ocean and meteorology, and research results of previous investigations in this area by the departments are all collected. The data include regional geology, hydrogeology, environmental geology, marine geology, hydrometeorology and active faults, etc.

(2) Field work. Field work which contains 1:100,000 hydrogeological survey 756.00km$^2$, 1:50,000 hydrogeological survey 200km$^2$ in key areas, hydrogeological drilling 390.1m /15 Wells, 57 pumping tests, and 85 electric sounding points, is completed.

(3) Sampling test. A total of 105 water quality analyses were conducted, including 90 wells and 15 drilling holes.

4. Calculation and evaluation of groundwater resources

4.1. Groundwater chemical analysis
A total of 105 water samples were collected in this paper, and the full analysis showed that there were eight types of hydrochemistry in the investigation area, namely Cl, HCO$_3$, HCO$_3$·Cl, HCO$_3$·SO$_4$, HCO$_3$·NO$_3$, NO$_3$·Cl, SO$_4$ and NO$_3$. The salinity was mostly above 0.3g/l, and the regional distribution was shown in figure 2. It can be seen from figure 2 that Cl water is mainly distributed near the estuarine area of Futuan river, Liangcheng river and Xiupin river. In this area, the terrain tends to be gentle, hydraulic gradient becomes slower, runoff speed becomes slower, water circulation conditions are poor, evaporation is strengthened, and hydrochemistry is mainly concentrated. The anions in the water are mainly Cl$^-$, and the cation is mainly Ca$^{2+}$, Na$^+$. HCO$_3$ and HCO$_3$·Cl water are widely distributed in the area, with unimpeded groundwater runoff and strong natural alternations. The groundwater chemistry is dominated by dissolution and filtration. The anions in the water are mainly HCO$_3^-$ and Cl$^-$, and the cation is mainly Ca$^{2+}$ and Na$^+$. Salinity less than 1g/L, good water quality. Water of HCO$_3$·SO$_4$ type, HCO$_3$·NO$_3$ type, NO$_3$·Cl type, SO$_4$ type and NO$_3$ type appeared sparsely in the surrounding towns, orchards, vegetable fields and other places. Urban garbage and a large number of agricultural pesticides and fertilizers were used in farmland, resulting in poor water quality and excessive SO$_4^-$ and NO$_3^-$ ions.

![Groundwater Chemical Distribution Map in the Investigation Area](image)
4.2. Calculation and evaluation of groundwater resources

Based on the hydrogeological information collected from the survey area, this paper calculated and evaluated the amount of groundwater resources in the survey area by analyzing the factors such as recharge, diameter and discharge of groundwater.

4.2.1. Groundwater recharge

(1) Precipitation infiltration supply in the investigation area

The calculation formula of precipitation infiltration supply in the investigation area is as follows:

\[ Q = P \times a \times F \times 10^{-1} \]  

where, \( Q \), \( P \), \( a \) and \( F \) represent precipitation infiltration supply \((10^4 \text{m}^3/\text{a})\), effective precipitation \((\text{m/а})\), precipitation infiltration coefficient, and calculated area \((\text{m}^2)\), respectively [9].

Precipitation is the average value of precipitation over many years. The precipitation infiltration coefficient of each hydrological zone is determined according to the lithology of the vadose zone. The calculated precipitation infiltration amount of the whole freshwater area is \(5693.0 \times 10^4 \text{m}^3/\text{a}\), as shown in table 2. Among them, the rainfall infiltration supply of loose rock pore water is \(4117.4 \times 10^4 \text{m}^3/\text{a}\), accounting for 72.32% of the total precipitation infiltration. The precipitation infiltration supply of bedrock fracture water is \(1575.6 \times 10^4 \text{m}^3/\text{a}\), accounting for 27.68% of the total precipitation infiltration.

| Partition | Unsaturated zone lithology | Annual average | Rainfall infiltration coefficient | Q \((10^4 \text{m}^3/\text{a})\) | Total Q \((10^4 \text{m}^3/\text{a})\) |
|-----------|-----------------------------|----------------|----------------------------------|-------------------------------|----------------------------------|
| Liangcheng River Basin Hydrology geologic area | Piedmont plain Piedmont alluvial plain | 870.2 0.6752752 | 10080000 0.24 | 163.4 | |
| | Residual alluvium | 870.2 0.6752752 | 44131600 0.18 | 536.4 | 1043.1 |
| | Exposed bedrock Granitic intrusive rock | 870.2 0.6752752 | 63543500 0.08 | 343.3 | |
| Futuang River Basin Hydrology geologic area | Piedmont plain Piedmont alluvial plain | 870.2 0.6752752 | 25415700 0.24 | 411.9 | |
| | Residual alluvium | 870.2 0.6752752 | 82689500 0.18 | 1005.1 | 1990.1 |
| | Exposed bedrock Granitic intrusive rock | 870.2 0.6752752 | 106090000 0.08 | 573.1 | |
| Jufeng River Basin Hydrology geologic area | Piedmont plain Piedmont alluvial plain | 870.2 0.6752752 | 8860000 0.24 | 143.6 | |
| | Residual alluvium | 870.2 0.6752752 | 92754200 0.18 | 1127.4 | 1600.2 |
| | Exposed bedrock Granitic intrusive rock | 870.2 0.6752752 | 60941400 0.08 | 329.2 | |
| Longwang River Basin Hydrology geologic | Piedmont plain Piedmont alluvial plain | 870.2 0.6752752 | 6694200 0.24 | 108.5 | 650.2 |
| | Residual | 870.2 0.6752752 | 26833200 0.18 | 326.2 | |


| area                                       | alluvium                                      |                          |                          |                          |
|--------------------------------------------|----------------------------------------------|--------------------------|--------------------------|--------------------------|
| Exposed bedrock                            | Exposed bedrock                              | 870.2                    | 0.6752752                | 39900000                 |
|                                            | Granitic intrusive rock                       |                          |                          |                          |
|                                            | Piedmont alluvial plain                       | 870.2                    | 0.6752752                | 3203000                  |
|                                            | Residual alluvium                            | 870.2                    | 0.6752752                | 20000000                 |
|                                            | Granitic intrusive rock                       | 870.2                    | 0.6752752                | 21180000                 |
| Xiuizhen River Basin Hydrology geologic area| Exposed bedrock                              |                          |                          |                          |
|                                            | Piedmont plain                               | 870.2                    | 0.6752752                | 21180000                 |
|                                            | Residual alluvium                            | 870.2                    | 0.6752752                | 20000000                 |
|                                            | Granitic intrusive rock                       | 870.2                    | 0.6752752                | 21180000                 |
| Total                                      |                                              |                          |                          |                          |
|                                            |                                              |                          |                          |                          |
|                                            |                                              |                          |                          |                          |

(2) River leakage supply

The groundwater level in the investigation area is closely related to the river level. Except for the Xiupin river, there are concentrated water supply sources on both sides of the river, which are exploited all year round. The groundwater level is lower than the river level all year round, and the river supplies groundwater for a long time. Groundwater exploitation in the middle and lower reaches of Xiupin river is relatively small. The surface water replenishes the groundwater in the rainy season and the groundwater replenishes the river in some areas in the dry season. During the statistical equilibrium period, the recharge underground water amount of each river is 2492.29×10^4 m^3/a. Among them, the recharge underground water amount of Liangchen, Futuan, Jufeng and Longwang river are 504.25×10^4 m^3/a, 1610.23×10^4 m^3/a, 221.90×10^4 m^3/a and 155.92×10^4 m^3/a, respectively [10].

(3) Recharge amount of groundwater runoff

The aquifer thickness of bedrock fissure water in the investigation area is small, and the permeability is poor, and the groundwater flow is mostly directed to the piedmont (middle) valley area, and the overall lateral runoff of bedrock fissure water is not large. Therefore, the groundwater runoff in this paper is only calculated as the runoff recharge of piedmont (middle) valley plain, and the calculation formula is as follows:

\[ Q_{sidein} = K \cdot M \cdot B \cdot I \times 365 \times 10^4 \]  (2)

where, \( Q_{sidein} \) represents lateral inflow (10^4 m^3/a), \( K \) is calculated section aquifer permeability coefficient (m/d), \( M \) is calculated section aquifer thickness (m), \( B \) is calculated section width (m), and \( I \) is calculated hydraulic gradient of the section [11]. The total lateral inflow is 453.09×10^4 m^3/a. Among them, the lateral inflow of Liangchen, Futuan, Jufeng, Longwang, Xiuja are 28.14×10^4 m^3/a, 309.32×10^4 m^3/a, 31.17×10^4 m^3/a, 25.02×10^4 m^3/a, 59.44×10^4 m^3/a, respectively

4.2.2. Groundwater consumption

(1) Lateral outflow

In this paper, only the runoff of piedmont valley plain was considered in the calculation of lateral runoff of groundwater, and the calculation formula was as follows:

\[ Q_{sideout} = K \cdot M \cdot B \cdot I \times 365 \times 10^4 \]  (3)

Where, \( Q_{sideout} \) represents lateral outflow (10^4 m^3/a); \( K \)- calculated section aquifer permeability coefficient (m/d); \( M \)- calculated section aquifer thickness (m); \( B \)- calculated section width (m); \( I \)- calculate the hydraulic gradient of the section [12]. The lateral outflow of the whole fresh water area was calculated as 329.50×10^4 m^3/a. Among them, the lateral outflow of Liangcheng, Futuan, Jufeng, Longwang and Xiuze are 49.63×10^4 m^3/a, 94.12×10^4 m^3/a, 126.28×10^4 m^3/a, 26.23×10^4 m^3/a and 33.24×10^4 m^3/a, respectively.

(2) Diving evaporation

The calculation formula of diving evaporation in the survey area is as follows:

\[ Q_{steam} = 0.1 \times E \cdot C \cdot F \]  (4)

where, \( Q_{steam} \) is diving evaporation (10^4 m^3/a), \( E \) is evaporation of water surface (m); \( C \) is evaporation coefficient, and \( F \) is calculated area (m^2) [13]. The calculated diving evaporation in the planning area
is 104.58×10^4 m^3/a. Among them, Liangcheng is 17.42×10^4 m^3/a, Futuan is 33.74×10^4 m^3/a, Jufeng is 33.51×10^4 m^3/a, Longwang river is 13.33×10^4 m^3/a and Xiuzhen is 6.58×10^4 m^3/a.

(3) Manual production

The amount of artificial exploitation in the survey area mainly includes urban domestic water, rural domestic water, agricultural mining and industrial mining. According to the survey, the amount of groundwater exploitation is about 5536.41×10^4 m^3/a. Among them, Liangcheng is 1033.82×10^4 m^3/a, Futuan is 3130.92×10^4 m^3/a, Jufeng is 775.68×10^4 m^3/a, Longwang is 417.47×10^4 m^3/a and Xiuzhen is 178.53×10^4 m^3/a.

In summary, there are eight types of hydrochemistry in the investigation area, including Cl, HCO₃, HCO₃·Cl, HCO₃·SO₄, HCO₃·NO₃, NO₃·Cl, SO₄ and NO₃. The salinity is mostly above 0.3g/l. Due to the large use of pesticides and fertilizers in urban refuse and farmland, the quality of water in some areas of the investigation area is poor, and SO₄ and NO₃ exceed the standard. In this paper, considering the comprehensive precipitation infiltration supplement amount, river leakage supplement amount and groundwater lateral runoff supplement amount, the total underground water supplement amount in the investigation area is calculated as 8638.40×10^4 m^3/a. Further, the lateral runoff excretion, diving evaporation and artificial exploitation of groundwater were calculated, and the total consumption of groundwater in the investigation area was 6017.12×10^4 m^3/a.

5. Optimization configuration analysis and research

In order to realize reasonable, sustainable and optimized utilization of groundwater resources in the investigated area, this paper mainly plans the prohibited and restricted exploitation areas according to the current situation of groundwater resources in the planned area.

5.1. The principle of prohibited mining areas and restricted mining areas division

(1) Prohibited mining area. This area is a serious over-mining area of groundwater, which has formed a large area of descending funnel and seriously deteriorated the quality of groundwater.

(2) Restricted mining areas. After the groundwater level in the planning area drops, the areas that restrict groundwater exploitation for the purpose of water conservation shall be classified as restricted mining areas.

5.2. Planning area division

According to the hydrochemistry and resource calculation of groundwater resources, this paper drew the development zone of water resources prohibition and restriction in Rizhao coastal area as shown in figure 3. The east area of the red line to the coastline is the no-mining area with a total area of 143.68km². The west area of the red line of restricted mining area to the red line of prohibited mining area is restricted mining area with a total area of 612.32km².
Above all, to achieve certain radioactive-polluted area of groundwater resources sustainable, optimizing the use of advice in a certain radioactive-polluted area each river coastal location research on feasibility of underground reservoir exploration and test, select favourable areas they ooze dam construction, the construction of underground reservoir, which can adjust the time and space distribution of surface water and groundwater, increased the groundwater can be mined, raise the utilization ratio of water resources.

6. Conclusion
In order to realize the virtuous cycle of groundwater resources and water ecosystem in Rizhao coastal area, this paper carries out the calculation and optimization analysis of groundwater resources in Rizhao coastal area by means of ground investigation, geophysical exploration, pumping test, water level measurement and sampling test, and fully considers the factors such as groundwater supplement, diameter and discharge. First of all, groundwater chemical is analysed in the investigation, there are eight types of hydrochemistry in the investigation area, including Cl, HCO₃, HCO₃·Cl, HCO₃·SO₄, HCO₃·NO₃, NO₃·Cl, SO₄ and NO₃. The salinity is mostly above 0.3g/l. Due to the large use of pesticides and fertilizers in urban refuse and farmland, the quality of water in some areas of the investigation area is poor, and SO₄ and NO₃ exceed the standard. The total groundwater recharge in the investigation area is 8638.40×10⁴m³/a, and the total groundwater consumption is 6017.12×10⁴m³/a. Secondly, on the basis of calculation and evaluation of groundwater resources in the investigation area, this paper delimits the exploration amount of groundwater resources and the hydrochemical properties of the investigation area to prohibit and restrict the development zone and puts forward reasonable mining opinions to realize the optimization and sustainable development of
groundwater resources in the investigation area. In order to carry out the feasibility exploration and experimental study of underground reservoirs in the coastal areas of the investigation area all rivers, favorable areas are selected to build underground seepage dams and build underground reservoirs which can adjust the spatial and temporal distribution of surface water and groundwater to increase the exploitable amount of groundwater and improve the utilization rate of water resources. This paper studies the measurement and optimal allocation of groundwater resources in coastal areas of Rizhao, which can not only effectively guarantee the development needs of Rizhao, but also has certain reference and practical value for the quantitative evaluation of groundwater resources in other areas.

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