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Analysis of the Characteristics of Groundwater Resources in the Section from Tongdu to Gela along the Xiaojiang River

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Abstract

In order to obtain the groundwater resource characteristics of Tongdu to Gele Member along Xiaojiang River, this paper firstly analyzes the lithology distribution characteristics of Tongdu to Gele Member along Xiaojiang River in Dongchuan District, then studies the lithology in the region through geological survey and geological drilling, and then analyzes the permeability coefficient of lithology in different regions by combining with corresponding hydrogeological tests. The water quality factor characteristics of the inland water in various regions along the Xiaojiang River were analyzed. Finally, according to the hydrogeological test results and water quality test results, the water-rich characteristics of some strata lithology exposed in the study area and the water quality characteristics of groundwater were summarized, and the pollution sources exceeding the standard water quality factors were preliminarily and simply analyzed. The conclusion and data of the study can provide feasibility support for the development and utilization of groundwater resources in this area in the future.

Keywords

Groundwater, Hydrogeological test, Water quality testing

Introduction

China is a country with relatively scarce water resources, characterized by uneven temporal and spatial distribution. Furthermore, due to the low efficiency in the development and utilization of water resources in some areas, most regions are currently facing the practical problems of water scarcity and poor water quality, which significantly impacts the local population's production, livelihood, and physical health [1]. The water resources along the Xiaojiang River in Dongchuan District exhibit abundant overall quantity but are characterized by seasonal uneven distribution, low development and utilization, and severe heavy metal pollution [2]. This paper aims at analyze the hydrogeological and water quality characteristics of the segment from Tongdu Town to Gele Village in the Xiaojiang Basin. The objective is to clarify the water resources features of this region and provide rational recommendations for groundwater extraction in the future.

1. Research scope and research methods

The scope of this study encompasses the foothill slope zone and the river terrace of the segment from Tongdu Town to Gele Village along the Xiaojiang River in Dongchuan District. The research methods employed include experimental and numerical approaches. Six hydrogeological boreholes were unevenly distributed within the study area, near densely populated villages and towns. After the completion of borehole placement, drilling, the casing installation and well flushing were carried out. Pumping tests were conducted once the boreholes produced clear water. This allowed the acquisition of hydrogeological parameters for the corresponding aquifers of the six hydrogeological boreholes. Finally, water samples of 10 liters were collected from each borehole for water quality testing. Based on the water quality test results, numerical methods were used to analyze the water quality characteristics of the groundwater within the study area.

2. Hydrogeological Characteristics

Based on the collective regional data, the geological structure in the study area is centered around the Xiaojiang Fault, with well-developed secondary structures. The development of lithological formations is relatively complete, with extensive distribution of underlying formations ranging from the Huangcaoling Formation of the Paleoproterozoic Changcheng System to the Qixia-Maokou Formation of the Permian Second Order Sequence. The overlying formations mainly consist of the Quaternary alluvial, lacustrine, and glacial deposits. Combining the geological mapping and lithology revealed by geological drilling, the lithological characteristics of the six hydrogeological boreholes and the natural spring Q1 is presented in Table 1.

Table 1. Lithological Characteristics of Each

Number		Lithological Characteristics
Tongdu Borehole		Overlying Quaternary residual slope deposits; underlying Cambrian Qiuzhushi Formation argillaceous sandstone, Cambrian Yucunhu Formation argillaceous dolomite
Tangdan Borehole		Overlying Quaternary artificial fill soil; Quaternary alluvial clay, silt, fine sand, organic soil, and rounded gravel layers; underlying Silurian Dengying Formation dolomite
Daduo Borehole		Overlying Quaternary alluvial rounded gravel and pebble layers; underlying Permian Maokou Formation limestone
Tuobuka Borehole		Overlying Quaternary artificial fill soil; Quaternary alluvial clay, rounded gravel, and pebble layers
Buwei Borehole		Overlying Quaternary artificial fill soil; Quaternary alluvial pebble and rounded gravel layers
Gele Borehole	CZK1	Overlying Quaternary debris flow accumulation with gravel soil, Quaternary slope residual debris with clay, gravel layers, etc.; underlying fractured zone within the fault zone distributed with fault breccia, cataclastic rocks, etc.
	CZK2	Quaternary alluvial clay, rounded gravel, and pebble layers
Spring Q1		Exposed Paleozoic Huangcaoling Formation dolomite

Based on the revealed formations from drilling and the water level variations during hydrogeological borehole drilling, it can be determined that all six hydrogeological boreholes belong to unconfined incomplete wells. According to relevant specifications:

(1) The formula for calculating the permeability coefficient is: $K = \frac{0.732Q}{(H+l)S}\lg\frac{R}{r}$ (Equation 1)

(2) The formula for calculating the influence radius is: (Equation 2)

In the formula: K is the permeability coefficient (m/d), Q is the discharge (m^3/d), H is the aquifer thickness (m), l is the length of the filter (m), S is the drawdown (m), R is the influence radius (m), and r is the borehole radius (m). The calculated parameters are listed in Table 2.

Table 2. Measured Hydrogeological Parameters of Each Borehole in the Study Area

Borehole Number		Drilling depth (m)	Q(m^3/d)	H(m)	l(m)	S(m)	R(m)	r(m)	K (m/d)	Groundwater Type
Tongdu Borehole		105.4	271.0	25.30	25.7	44.47	445.8	0.075	0.33	Fracture Water
Tangdan Borehole		131.19	135.36	40.06	32.19	30.38	114.88	0.078	0.143	Karst Water
Daduo Borehole		130.61	303.6	81.93	74.9	7.03	53.3	0.079	0.56	Karst Water
Tuobuka Borehole		61.5	257.0	49.48	49.21	0.3	10.13	0.102	14.09	Pore Water
Buwei Borehole		59.8	172.0	51.49	15.0	0.59	10.86	0.230	11.51	Pore Water
Gele Borehole	CZK1	105.76	No water level was seen							/
	CZK2	48.1	144	27.48	24.1	4.1	48.1	0.065	1.43	Pore Water
Spring		/	1312.4	/	/	/	/	/	/	Karst Water

Based on the measured hydrogeological parameters in Table 2, the following conclusions can be drawn:

(1) The Lower Cambrian Qiuzhushi Formation black argillaceous sandstone in the southern part of the study area has a permeability coefficient of 0.33 m/d, indicating a weak ~ moderately permeable characteristic. The specific discharge is 0.07 L/s.m, indicating a weak w.

(2) In the eastern part of the study area, the lower member of the Permian Second Order Sequence, Qixia-Maokou Formation, consists of limestone, dolomitic limestone, and dolomite of the upper member of the Cambrian System, Dengying Formation. The permeability coefficients of these formations are 0.56 m/d and 0.143 m/d, respectively, indicating weak to moderate water permeability. The specific yield values are 0.499 L/s • m and 0.051 L/s • m for the respective formations, indicating a moderate water-bearing capacity for the limestone and dolomitic limestone of the Qixia-Maokou Formation and a weak water-bearing capacity for the dolomite of the Dengying Formation.

(3) In the central part of the study area along the Xiaojiang River, the Quaternary Holocene Pleistocene alluvial gravel and pebble layers have a permeability coefficient ranging from 4.2 to 14.09 m/d, with an average of 9.93 m/d, indicating a high water permeability. The specific yield values is 9.915 L/s • m, 3.374 L/s • m, and 0.40 L/s • m, respectively, indicating significant variations in water-bearing capacity within the Quaternary alluvial gravel and pebble layers, which are related to the clay content of local gravel and pebble layers.

(4) Drillhole CZK1 in Gele Village reaches a depth of 105.67 m without encountering the water level. Based on the analysis of the drill core, it is determined that a small fault passes near Gele Village, which acts as a barrier for water flow.

3. Water Quality Characteristics

After hydrogeological testing in each hydrogeological drillhole, 10 liters of water samples were collected from each drillhole and sent to qualified testing institutions for analysis of seven major cations and anions: K+, Na+, Ca2+, Mg2+, CO32-, HCO3-, Cl-, and SO42-.Additionally, 22 water quality factors were analyzed, including pH value, total hardness, sulfates, chlorides, iron, manganese, copper, zinc, volatile phenol, anionic synthetic detergents, permanganate index, nitrates, ammonia nitrogen, fluorides, cyanides, mercury, arsenic, selenium, cadmium, hexavalent chromium, lead, aluminum, total coliform, and total colony count. The statistical analysis of the major cations and anions in the water samples is presented in Table 3.

Table 3. Major cation and anion concentrations and hydrochemical types of water samples in the study area

Ion Concentration(mg/L) Drillhole ID	K^++Na^+	Ca^{2+}	Mg^{2+}	CO_3^{2-}	HCO_3^-	Cl^-	SO_4^{2-}	Hydrochemical Type (Schoeller Method)
Tongdu Borehole	29.1	84.4	29.4	0	196.6	17.8	170.9	SO_4-HCO_3--Mg-Ca
Tangdan Borehole	14.3	104.2	65.5	0	122.0	10.6	343.0	SO_4-HCO_3--Mg-Ca
Daduo Borehole	17.8	104.2	87.5	0	107.8	10.6	366.0	SO_4-HCO_3--Mg-Ca
Tuobuka Borehole	37.2	356.7	221.2	0	268.5	7.1	1430.0	SO_4-HCO_3--Mg-Ca
Buwei Borehole	95.5	236.5	162.9	0	286.8	14.2	1087.5	SO_4-HCO_3--Mg-Ca
Gele Borehole	68.5	289.7	155.3	0	256.8	11.3	1123.4	SO_4-HCO_3--Mg-Ca

Based on the statistical analysis of major cations and anions in Table 3, according to the Schoeller classification method, the groundwater and major surface water in the study is a are classified as SO4-HCO3-Mg-Ca type water [3]. The pH values range from 7.16 to 8.27, indicating a weak alkaline nature. According to the "Groundwater Quality Standards" (GB/T 14848-2017), Class III water is suitable for centralized domestic water supply and industrial and agricultural water use. Therefore, Class III water quality standards were used to evaluate whether the water quality exceeded the standards. The analysis results of the 22 water quality factors for the six groups of water samples are as follows:

(1) Copperdu drillhole exceeded water quality standards for the following factors: total hardness (Class V), sulfates (Class V), manganese (Class IV), ammonia nitrogen (Class IV), and total colony count (Class IV).

(2) Tangdan drillhole exceeded water quality standards for the following factors: total hardness (Class IV), sulfates (Class IV), manganese (Class IV), and total colony count (Class IV).

(3) Daduo drillhole exceeded water quality standards for the following factors: total hardness (Class IV) and total coliform count (Class IV).

(4) Tuobuka drillhole exceeded water quality standards for the following factors: total hardness (Class V), sulfates (Class V), manganese (Class IV), and total colony count (Class IV).

(5) Buwei drillhole exceeded water quality standards for the following factors: total hardness (Class V), sulfates (Class V), manganese (Class IV), and total colony count (Class IV).

(6) Gele drillhole exceeded water quality standards for the following factors: total hardness (Class V), sulfates (Class V), manganese (Class V), the permanganate index (Class IV), ammonia nitrogen (Class IV), and total colony count (Class IV).

4. Pollution Source Analysis

Based on the analysis of the 29 water quality indicators of the six water samples, the indicators that exceeded Class III water quality standards are mainly total hardness, sulfates, manganese, permanganate index, ammonia nitrogen, total coliform, and total colony count. Based on the geological and environmental conditions, the analysis is as follows:

(1) The excessive levels of total hardness, sulfates, manganese are primarily due to the presence of a large amount of mineral in the rock formations along the Xiaojiang River, and the dissolution of trace minerals in the groundwater leads to high concentrations of total hardness, sulfates, and manganese.

(2) The excessive levels of permanganate index, ammonia nitrogen, total coliform, and total colony count indicate that the groundwater is influenced by surface water recharge, which contains inorganic and organic pollutants. The pollution sources may originate from wastewater discharge from surrounding industries and residential sewage [4].

5. Analysis of Prospects for Groundwater Extraction in the Study Area

(1) The study area in the Copperdu to Gele section along the Xiaojiang River in Dongchuan District has various types of groundwater, including pore water, fissure water, and karst water, indicating favorable geological conditions for groundwater extraction.

(2) The Lower Cambrian Qiongzhusi Formation in the southern part of the study area has low water-bearing properties, making groundwater extraction relatively difficult. The Xiaoxiang Formation in the eastern part of the study area, including the Qixia-Maokou Formation limestone and the Dengying Formation dolomite, has moderate water-bearing properties, while the Upper Sinian Dengying Formation dolomite has low water-bearing properties. Both these formations have some potential for groundwater extraction.

(3) The groundwater in the study area is influenced by the lithology of the geological strata and surface water recharge. There are seven indicators, including total hardness, sulfates, manganese, permanganate index, ammonia nitrogen, total coliform, and total colony count, that exceed the Class III water quality standards. Therefore, groundwater extracted should not be directly used as drinking water, but it can be utilized for industrial and agricultural purposes.

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