Study on dynamic characteristics of Karst Spring in Jinan

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Abstract. In order to ensure the efficient and reasonable utilization of groundwater and the sustainable development of groundwater systems in Jinan City, a hydrogeological survey was conducted in the study area of the spring area, collecting groundwater dynamic observation data over the years, and sampling and testing the water chemistry of the spring water. The characteristics of spring water flow and spring water chemical dynamics comprehensively summarize the spring water dynamics. Research shows that besides the influence of precipitation, the water level of Baotu Spring is also affected by the discharge of Wohushan Reservoir and various recharges, especially artificial supplementary measures have played a certain role in maintaining the water level attenuation of Baotu Spring during the dry season; The change law of spring water flow and groundwater level is the result of the combined effects of direct recharge of atmospheric precipitation, indirect recharge of river leakage, and groundwater excretion; due to the influence of human activities, the conventional ion composition of spring water has an upward trend. The research results provide technical basis for spring water protection.

1. Introduction
China’s karst groundwater is widely distributed, with a concentrated distribution and large spring flow in the northern region, which plays an important role[1]. Shandong Province is one of the provinces with extensive karst distribution in northern China. Jinan City, as the capital of Shandong Province, has the Baotu Springs, Heihuquan Spring Group, Wulongtan Spring Group and Pearl Spring Spring Group. In the late 1950s and early 1960s, springs flowed year round. However, with the development of Jinan's cities, the demand for water continues to increase, the karst groundwater in the spring area of Jinan area is becoming increasingly scarce, and the flow of spring water is declining. For many years, many experts
have carried out analysis of the causes of karst water resources and spring flow attenuation in the spring area of Jinan. The research work[2-5], in order to reasonably develop, utilize and protect the karst groundwater resources of the Jinan spring group, it is necessary to study the dynamics of karst groundwater in the spring area. Based on the collected groundwater dynamic observation data, this paper carried out spring water level dynamics, spring water Research on the flow and spring water chemistry dynamic characteristics, with a view to providing a basis for future management and development of karst groundwater resources.

2. Geological profile of the study area

Jinan City is located in the central and western part of Shandong Province, The geographical position is 116°11′~117°44′ east longitude and 36°02′~37°31′ north latitude. Jinan spring area is located in the inland mid-latitude zone, and the climate type is warm temperate continental climate. The average annual temperature is about 14.2 °C, and the average annual rainfall is around 646.55mm. Jinan spring area is located in the transition zone between the mountains in the middle of Shandong and the sloping plain in front of the mountain. The terrain is generally high in the south and low in the north, high in the east and low in the west. It gradually rose to the north again. The western part of the spring boundary is bounded by the Mashan fault; the northern Jinan rock mass and Carboniferous and Permian strata are used as its northern boundary; the eastern part is bounded by the Dongwu fault, The area is 845.5km².

3. Study on Spring Water Dynamic Characteristics

3.1. Dynamic characteristics of spring water level

3.1.1. Dynamic characteristics of spring water level during the year

In addition to the obvious control of regional agricultural centralized irrigation irrigation, groundwater level dynamics is also closely related to the spatial and temporal distribution of precipitation. Under the condition that groundwater extraction remains unchanged, precipitation is the most important factor determining the dynamic change of groundwater level.
Agricultural irrigation, groundwater exploitation and spring outflow are the main consumption factors of groundwater. From the dynamic curve of water level and precipitation of Baotu Spring, it can be seen that there is a decline rise decline process from April to June every year. In addition to being affected by precipitation, the water level of Baotu Spring is also affected by the water discharge of Wohushan reservoir and various recharge, which slows down the decline trend of groundwater level. The measures of recharge and replenishment have played a certain role in maintaining the water level of Baotu Spring.

3.1.2. Dynamic characteristics of interannual spring water level

The main factors affecting the dynamics of groundwater level in Jinan urban area are the replenishment of atmospheric precipitation and the drainage of groundwater. The increase in the amount of mining reduces the level of karst water, reduces the flow of springs, and even the springs will lose flow during the dry season.

In the 1950s and 1960s, the amount of groundwater exploitation was small, less than 100,000 m$^3$/d, spring water spouted all year round, and the water level in the urban area was about 31m. By the 90-year dry season, the water level had dropped to 20.8 meters, and the spring water had been stopped for hundreds of days. After 2001, Jinan City strictly controlled the exploitation of groundwater, and the spring water level continued to rise. By 2003, the Baotu Spring, which had been stopped for 548 days, finally resumed gushing. So far, Baotu Spring has achieved gushing for 15 years.

In the history of groundwater extraction in the research area for many years, the karst water level has generally declined-rises-falls-rises-falls-rises-falls-rises-steady nine large wave-like dynamic changes, and the dynamic changes of the water levels for many years are mainly controlled by Impact of mining volume, previous year and current year precipitation (Figure 4).

3.2. Dynamic characteristics of spring flow
3.2.1. Flow characteristics during the year

According to the spring flow data (Figure 3), the average flow of spring water in Jinan City was 146400 m$^3$/d, which was higher than the average flow of 92700 m$^3$/d and 142000 m$^3$/d in 2014 and 2015.
3.2.2. Interannual flow dynamics

The dynamic flow of spring water in Jinan city is basically consistent with the dynamic change of the karst groundwater level near the Four Great Springs Group. Over the years, the overall trend of attenuation has been shown. Among them, within a year or between years, the flow of spring water changes with the increase of groundwater level—decreasing—increasing—decreasing—increasing(Figure 4).

The total flow of spring water in the four major springs of Jinan City in normal years is about 200,000 m³/d. In the 1950s, the total flow of the four major springs in Jinan was 300,000 to 350,000 m³/d. With the gradual increase in the amount of karst water, the flow of spring water in Jinan is decreasing. The large-scale exploitation of groundwater has caused seasonal outflows of the Jinan Spring Group, and even cut off the flow several times throughout the year. Among them, from 1999 to 2001, the amount of precipitation in Jinan City was relatively small. The groundwater level in the urban area was always below the discharge elevation of Baotu Spring at 26.8m, and the spring water flow continued for 926 days.

Figure 3. Spring water flow dynamic graph

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3.3. Chemical characteristics of spring water

3.3.1. Characteristics of water chemical composition

The hydrochemical profile was drawn using karst water quality data along the Chaomidian-Wenzhuang-Urban Heihuquan-Dongjiao-Baiquan line. The profile is from the fried rice shop in the piedmont of the Yufu River Basin to the Baiquan drainage area in eastern Jinan. The main water intake levels are mainly the aquifers of the Majiagou Formation and the Sanshanzi Formation of the Ordovician.

The sampling points are located in Chaomidian, Yinjialin, Xiaobaizhuang, Wenzhuang, Houlongwo, Shuanglong, Quancheng Park, Heihuquan, Niwangzhuang, and Yangbei and Baiquan, which are located east of the spring boundary (Figure 5).

In general, the groundwater in the various sections of Baotu Spring Springs Fried Rice Shop-Heihuquan-Baiquan showed the following hydrochemical characteristics:

1. The groundwater hydrochemical index of the aquifer in the Sanshanzi Formation is relatively lower than that of the Ordovician Majiagou Formation, and the water quality is relatively stable. The difference in groundwater hydrochemical indicators in different sections
is small.

(2) TDS and Ca$^{2+}$ have the same trend in the dissolvable total solids of groundwater in various sections, and the degree of coincidence between TDS and Ca$^{2+}$ is high and the correlation is high.

3.3.2. Hydrochemical dynamics and trends

According to the monitoring data of water quality for many years, the water quality index of karst water in the area is generally on the rise year by year, especially since the 1980s, the chemical component content of karst water has increased rapidly. The water chemistry indexes such as SO$_4^{2-}$, Cl$^-$, NO$_3^-$, salinity and total hardness of the main water sources in Jinan are increasing year by year.

The quality of spring water and karst groundwater in urban area is good, TDS is generally lower than 600mg/l, which is HCO$_3$-Ca type water. Since 2004, the chemical composition of groundwater in urban water source area has also shown an upward trend (Figure 6).

In Baotu Spring and other urban springs, the content of each component is increasing; in addition, the northern part is blocked by magmatic rock mass, and the groundwater runoff is not smooth, so it can only be discharged in the form of spring or artificial mining, and some ions are continuously accumulated in the groundwater.

![Figure 6. Multi year dynamic change and trend prediction chart of karst groundwater](image)

According to the prediction of the formula, the total hardness of Cl$^-$, SO$_4^{2-}$, NO$_3^-$ will reach 53mg/l, 95mg/l, 42mg/l and 369mg/l in 2025.

4. Protection measures of karst spring

(1) Strictly control the exploitation of karst groundwater, prohibit new drilling of karst water wells, and strengthen the dynamic monitoring of karst groundwater, and reasonably arrange the karst groundwater quality and water level monitoring network.

(2) For the completed area, the community can be transformed according to the actual situation, such as changing the green space into a rainwater collection ecological landscape zone, adding seepage wells, etc., so that the rainwater can replenish the source.

(3) To prevent infiltration and replenishment of water quality pollution, various types of
sewage and solid waste need to be strictly harmlessly treated and can be discharged after reaching the standard.

5. Conclusions
(1) From the dynamic curve of the water level and precipitation of Baotu Spring, it can be seen that a decline-rise-fall process occurs from April to June every year, indicating that in addition to the impact of precipitation, various recharge and recharge measures have been carried out to maintain the spring level played a role.
(2) The dynamic flow of spring water in Jinan City is basically consistent with the dynamic change of karst groundwater level near the Four Great Springs Group. Over the years, it has generally declined, indicating that spring flow is directly replenished by atmospheric precipitation, indirect recharge from river leakage, and groundwater excretion. Comprehensive impact.
(3) According to the prediction of the formula, the total hardness of Cl-, SO42-, NO3- will reach 53mg/l, 95mg/l, 42mg/l and 369mg/l in 2025.

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