Impact Features of Water Source Mining on Spring Groups in Jinan City

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Abstract. In order to protect Jinan spring. This article is based on the research and analysis of the observation water level, extraction volume, spring water level, and observation data of water sources in West Jinan, western suburbs, and urban areas. It is concluded that: (1) According to the analysis of the dynamic type of groundwater level, there is a close hydraulic connection between the groundwater of West Jinan and Baotu spring spring group, which is a unified body of water with strong connectivity. (2) From the analysis of multi-year water level, spring discharge and mining volume, the impact of karst water mining in the western suburbs on the water level and spring discharge of urban spring water is very obvious. (3) The increase in the amount of karst water in the urban area and the decrease in the flow of spring water are very similar. Therefore, Jinan spring water is obviously affected by artificial mining. Controlling the amount of groundwater extraction, especially in urban areas, is of great significance to ensure the spring water gushing all year round. At the same time, it is necessary to make a good mining layout for the water sources in the western suburbs, West Jinan and eastern suburbs.

1. Introduction

Spring water is an important support for urban water use in Jinan. As an important source of Jinan spring water, karst water has played an important role in social and economic development and people's production and life [1]. In recent decades, with the continuous expansion of Jinan's cities, rapid economic development, and increasing population, water resources have begun to face shortages. In order to alleviate the shortage of water for production, living and agriculture, a large amount of karst water has been exploited in the spring within a short period of time. With the gradual increase in the amount of karst water exploitation, the spring water has been frequently cut off since 1972 [2], and it is urgent to carry out spring water protection.

From the perspective of water supply and ecological maintenance, many scholars have successively established Holt-Winters exponential smoothing models to perform groundwater simulation, prediction,
and propose effective water conservation and spring protection measures [3-5]. Probing the impact of the exploitation of the water source place on the spring water level will help to grasp the source of groundwater recharge, the direction of runoff, and the way of drainage, and make reasonable use of groundwater.

This article analyzes the impact of water level observations, pumping and stopping tests, and large-scale pumping tests on spring water based on the exploitation of water sources in the western suburbs, eastern suburbs, and urban water sources of Jinan City, combined with hydrogeological conditions in the study area, and provides spring protection for Baoquan. Significant research significance.

2. Overview of the study area
The south of the monoclinic structure of Jinan is a low-lying hilly area. The Cambrian and Ordovician limestone are exposed, and the surface karst is developed, which is easy for the infiltration of atmospheric precipitation(fig.1). Underground limestone karst caves, pores, crevices, and dissolution pipelines are relatively developed, providing huge space and channels for the storage and movement of groundwater(fig.2). Under the high head pressure, the southern fractured karst water flows northward along the terrain slope and stratigraphic occurrence, and recharges to the urban spring water through the surface karst fissures, pores, karsts, and underground fractures. The main way of runoff.

![Figure 1. Hydrological and geological map of Jinan Springs](image-url)
3. Research methods

Collected the data of mining volume in the western suburbs in 1990-2005, observation of spring water level, and observation data of spring water loss, data of West Jinan pumping test in 2002-2003, data of Baotu spring water level, urban mining volume and spring water in 1960-1979 Traffic data.

4. Results and discussion

4.1. Impact of the exploitation of water resources in West Jinan on spring water

West Jinan water source area mainly refers to the Qiaozi Li and Lengzhuang water source areas west of the western suburbs water source areas and east of the Mashan fault. In order to demonstrate the hydraulic connection between West Jinan and the urban area, the West Jinan Pumping Test was carried out in 2003. The total pumping volume in West Jinan and the western suburbs reached 310,000 m$^3$/d. The water level dynamic curve is shown in Fig. 3. During the pumping test, except for the increase in the pumping volume of the West Jinan test, other factors (precipitation, agricultural irrigation, etc.) had the same effect on the groundwater level. Before the pumping test, the water level of Songzhuang Station decreased by 1.31m in 2003, with an average daily decrease of 0.087m; the water level of Baotu Spring Station decreased by 1.34m, with an average daily decrease of 0.089m. In the same period of 2002, the water level of Songzhuang Station decreased by only 0.36m; Baotu Spring Station decreased by only 0.34m.

![Figure 2. Hydrogeological section of West Jinan-Western Suburb-urban area](image)

![Figure 3. Comparison curve of water level changes during Songzhuang and Baotu spring stations in 2003 and the same period in 2002](image)
The above two sets of data are in the dry season, and the groundwater level is in a state of natural decline. The difference in the decline in water level fully illustrates that not only does West Jinan pumping directly cause a significant decline in groundwater levels in the west, but also has a significant impact on the Baotu Spring in the urban area. There is a close hydraulic connection between the groundwater in West Jinan and the groundwater in the urban area. Uniform body of water.

4.2. Impact of the exploitation of water sources in the western suburbs on spring water

Based on the data of groundwater level, rainfall, and the amount of spring water exploitation from 1990-2005, we can draw the dynamic change of the mining of the water source of Dayangzhuang in the water-rich section of the western suburbs of Baotu Spring Spring (Fig. 4), which can be seen Before 2000, the rainfall and the amount of spring mining had a certain effect on the water level in Dayangzhuang. In order to protect the continuous gushing of spring water, since 2000, the urban and western suburban water sources have been gradually closed, and the total groundwater extraction in the spring has been reduced from 500,000 to 600,000m³/d to 300,000m³/d. After 2008, the surface water Groundwater sources are continuously replaced, and the total groundwater production continues to drop to about 200,000 m³/d. With the drastic reduction of groundwater extraction, the groundwater level began to rise continuously (Fig. 4). The groundwater level of Dayangzhuang Water Plant in the western suburbs gradually increased from about 25m in the 1990s to nearly 30m in 2015. The consistency of rainfall and water level The change shows that artificial mining has a very significant impact on the water level in the water-rich section of the western suburbs.

(Q—mining volume, spring discharge, unit 10,000 m³/d, P—precipitation value/after 20, reflecting the trend of change, H—karst water level elevation)

Figure 4. Dynamic changes of mining in Dayangzhuang water source area in the water-rich section of the western suburb of Baotu Spring

Table 1 Comparison table of spring water level and discharge under different mining conditions in the western suburbs

| Stage | Year   | Spring Area Water Level(m) | Urban mining(10⁴m³/d) | spring flow(10⁴m³/d) | Precipitation(mm) | Increased production in the western suburbs(10⁴m³/d) |
|-------|--------|----------------------------|-----------------------|----------------------|-------------------|-----------------------------------------------|
| I     | 1967-1974 | 28.75-28.68                | 21.31                 | 17.83                | 638.35            |                                               |
| II    | 1975-1982 | 28.15-26.46                | 27.73                 | 10.94                | 639.9             | 5                                            |
From years of water level, spring discharge, and mining volume analysis, increasing mining in the western suburbs, without increasing mining in other areas, the water level in urban areas has dropped significantly. It can be seen in Table 1 that the sum of the average urban mining volume and the average spring water flow in phases I and II are $39.14 \times 10^4$ m$^3$/d and $38.67 \times 10^4$ m$^3$/d, which are basically equal, and the precipitation in the two phases is basically the same. Due to increased mining in the western suburbs of Phase II, the average water level in the urban area dropped from 28.15m in 1975 to 26.46m in 1982. This shows that the impact of karst mining in the western suburbs on the water level and spring discharge of urban spring water is very obvious.

4.3. Impact of urban water source mining on spring water

The water plant in the south of the city is located in the same place as the four major springs, and they are very close to each other. For example, Baotu Spring is only 900m away from Pulimen Water Plant, and Heihu Spring is less than 1000m away from Jiefangqiao Water Plant. The funnel is bound to affect the spring area, causing the water level in the spring area to drop, affecting its water level and discharge. The relationship between the urban mining volume and spring water flow is shown in Table 2.

| Year | Spring water flow | Mining volume in urban area | Spring flow + Mined | Mining spring volume | Mining volume increase |
|------|------------------|----------------------------|--------------------|----------------------|-----------------------|
| 1960 | 31.05            | 9.56                       | 40.70              | 0                    | 0                     |
| 1971 | 16.41            | 23.52                      | 39.93              | 14.64                | 13.87                 |
| 1976 | 12.50            | 28.27                      | 40.77              | 18.55                | 18.62                 |
| 1979 | 10.05            | 30.60                      | 40.65              | 21.00                | 20.95                 |

Note: spring water reduction and recovery are relative to 1960

The analysis of multi-year spring water dynamic observation data shows that in the years with moderate rainfall, the increased exploitation amount of karst water in the urban area is very similar to the flow amount of the decreased spring water. The data in table 2 shows that the increased exploitation amount is close to that of the decreased spring water, and the exploitation amount in the urban area comes at the expense of the spring water flow.

5. Conclusion

(1) According to the analysis of the dynamic type of groundwater level, there is a close hydraulic connection between the groundwater in West Jinan and the Baotu spring spring group, which is a unified body of water with strong connectivity.

(2) From the analysis of the water level, spring discharge and mining volume for many years, the impact of karst water mining in the western suburbs on the water level and spring discharge of urban spring water is very obvious.

(3) Analysis of the observation data of dynamic spring water for many years shows that the increase in the amount of karst water in the urban area and the decrease in the flow of spring water are very similar in the years of normal precipitation.

(4) Jinan spring water is obviously affected by artificial mining. Controlling the amount of groundwater extraction, especially in urban areas, is of great significance to ensure the spring water spouts. At the same time, it is necessary to make a good mining layout for the water sources in the western suburbs, West Jinan and eastern suburbs.

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