Study on the genetic characteristics of spring water in four spring groups of Jinan

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Abstract. In order to protect the four spring groups in Jinan, it is very important to study the formation characteristics of the karst spring in Jinan. Based on the geological and hydrogeological conditions of Jinan spring group outcropping area, this paper makes a comprehensive study on the karst aquifer void type, spring water supply source, spring water gushing state, spring water flow, spring water temperature and conductivity, spring water chemistry data in the recharging area, so as to determine the genetic types of four spring groups. The results are as follows: (1) Baotu spring and Heihu spring have a similar genetic structure, their circulation depth is relatively shallower, and they are greatly affected by Ordovician karst water in the direct recharging area. Tanxi spring and Pearl spring have a similar genetic structure with a deeper circulation depth, which are greatly affected by Cambrian karst water in the indirect recharging area. Tanxi spring and Pearl spring have a similar genetic structure with a deeper circulation depth, which are greatly affected by Cambrian karst water in the indirect recharging area; (2) Baotu spring and Heihu spring are long-running cold springs recharged by confined water, which belong to erosion rising spring; Pearl spring and Wulongtan are long-running large and medium-sized cold springs recharged by pressurized water, which belong to contact rising spring. The research on the genetic characteristics of spring provides a scientific basis for spring protection in Jinan.

1. Introduction
The karst area in China is widely distributed, which is the main water supply source for many areas [1]. The groundwater system in Jinan karst spring area is complex, which is a typical representative of the northern karst. The in-depth study of Jinan karst spring area is of great significance to the groundwater resources and environmental protection in North China Karst Spring area [2]. With the rapid development of urbanization, environmental pollution, ecological damage and other problems are increasingly serious. The environmental capacity of karst water system is damaged, and the quality and flow of spring water are greatly affected [3].

Therefore, it is very important for spring protection in Jinan. It is also instructive to find out the genetic characteristics of spring in Jinan. Groundwater hydrochemistry data can not only reflect the
temporal and spatial variation characteristics of groundwater quality, but also provide means for the research of groundwater supply source, runoff path, circulation depth, hydraulic connection, which is also of significance for identifying different spring genetic types [4]. The study on the genetic characteristics of spring water is also helpful to further analyze the aquifer distribution, water yield, groundwater type, physical properties and chemical composition of groundwater, master the source of groundwater supply, runoff direction and discharge mode, which can provide basis for the study of groundwater dynamic balance and rational development and utilization.

Based on the characteristics of karst water chemical spatial distribution in spring and recharge area, as well as the changes of spring conductivity and temperature, combined with the hydrogeological conditions in the study area, this paper analyzes the genetic characteristics of the four spring groups, which has certain indicative significance for spring water protection.

2. Hydrogeological profile 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. Underground limestone karst caves, pores, gaps, and dissolution pipelines are relatively developed, providing huge space and passage for groundwater storage and movement. Under high head pressure, the 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 fissure karst networks, which is the main way of recharging karst water. Loose rock-type pore water, intrusive rock-type fissure water, and carbonate rock-type fissure-karst water are distributed from top to bottom near the spring water outcropping area.

The four spring groups are supplied by runoff from East, South and west to spring discharge area, and the four spring groups are supplied by karst water of Zhangxia group and karst water of Fengshan group and Ordovician system.

3. Research method

The collection of karst water samples controls the main recharge area of karst water from each aquifer to the spring group, and can control the process of groundwater supply, runoff and discharge. Shukarev classification was used to get the hydrochemical types of different springs and the conductivity and temperature of spring water are monitored by daily data.

4. Results and discussion

4.1. Chemical types of the four main spring groups

Due to the influence of different lithology and runoff conditions, there are some differences in the types of hydrochemistry. In general, the Ordovician karst water hydro-chemical type in the direct recharging area is mainly HCO₃·SO₄-Ca type, and the Cambrian karst water chemical type in the indirect recharging area is mainly HCO₃-Ca type. The lengthening and water-rock interaction strengthen, and the hydro-
chemical type gradually transitions from $\text{HCO}_3\cdot\text{Ca}$ type to $\text{HCO}_3\cdot\text{SO}_4\cdot\text{Ca}$ type. The chemical types of Baotu Spring and Black Tiger Spring are $\text{HCO}_3\cdot\text{SO}_4\cdot\text{Ca}$, and the chemical types of Tanxi Spring and Pearl Spring water are $\text{HCO}_3\cdot\text{Ca}$.

4.2. Electrical conductivity and temperature dynamic characteristics

According to the field conductivity monitoring data (Figure 3), the conductivity of the Four Great Springs Group has a certain correlation, and the Heihu Spring has the largest conductivity, followed by Baotu Spring, Tanxi Spring, and Pearl Spring. The conductivity changes of Heihu Spring and Baotu Spring are relatively unstable, and the variation is large.

The correlation between spring water temperature and atmospheric temperature is relatively large. Pearl Spring has the highest temperature, followed by Tanxi spring, Heihu spring and Baotu Spring. The average water temperature of Baotu Spring, Heihu spring, Tanxi spring and Pearl spring are 17.40°C, 17.34°C, 17.68°C and 17.71°C respectively.

4.3. Genetic characteristics analysis of the four springs

Based on the chemical analysis of the spring and the karst water in the recharge area, the Pearl Spring and Tanxi spring are $\text{HCO}_3\cdot\text{Ca}$ type, and the conductivity is relatively low and the temperature is relatively high. Baotu spring and Heihu spring are $\text{HCO}_3\cdot\text{SO}_4\cdot\text{Ca}$ type, and the conductivity is relatively high and the temperature is relatively low. It can be seen that the genetic structure of Baotu spring and Heihu spring is relatively similar, and the genetic structure of Tanxi spring and Pearl spring is relatively similar. The conductivity of karst water in Ordovician aquifer in the direct recharging area is relatively low, and the hydro-chemical type is mainly $\text{HCO}_3\cdot\text{SO}_4\cdot\text{Ca}$; the conductivity of karst water in Cambrian aquifer in the indirect recharging area is relatively low, and the hydro-chemical type is mainly $\text{HCO}_3\cdot$
Ca. Due to the influence of geothermal gradient, the temperature of groundwater in the deep Cambrian aquifer is significantly higher than that in the relatively shallow Ordovician aquifer. It can be inferred that the Ordovician aquifer in the direct recharging area has a greater impact on Baotu spring and Heihu spring, the depth of recharging cycle of spring group is shallower, and the Cambrian aquifer in the indirect recharging area has a greater impact on Tanxi spring and Pearl spring, and the depth of circulation of spring group is deeper.

According to the exposure conditions, the spring types can be generally divided into contact spring, erosion spring, overflow spring and fault spring. Among the four spring groups, Baotu spring and Heihu spring group are near the outcropping area. Among the four major spring groups, near the outcrop area of Baotu spring and Heihu spring Group, due to long-term weathering and erosion and water erosion, the Jurassic intrusive gabbro was cut through the water barrier, exposing the carbon The carbonate karst aquifer formed two carbonate rock “skylights”, and the upper part was covered by the late Pleistocene cemented limestone conglomerate. Karst water forms spring water through the conglomerate cracks and pores where the water layer in the "skylight" area contacts the impervious roof. According to the exposure conditions, Heihu spring and Baotu spring should be erosion springs.

Pearl spring and Wulongtan spring groups have similar outcropping conditions. The Jurassic intrusive gabbro is not completely weathered and eroded near its outcropping area, and its residual thickness is 50.8-60.5m. Their upper part is covered with more than ten meters of conglomerate and silty clay layer. The karst water is below the gabbro rock body, where the rock body and carbonate rock contact, along the condensation fractures and structural fractures along the edge of the rock body. Surge and exit the pores of the loose layer. Therefore, Pearl Spring and Wulongtan spring group can be called contact zone springs.

According to the types of aquifer voids, they can generally be divided into three categories: karst springs, fissure springs and pore springs. The groundwater that recharges the four major springs is stored in karst caves, eroded pores, and karst fissures formed by the development of structural fissures, and becomes the stable source of the four major springs. According to the source of spring water recharge, it can be divided into rising springs and falling springs. Spring water will gush only when the karst water head is higher than their lowest outflow level, and the karst water has obvious pressure-bearing properties under the upper barrier. Therefore, the four major spring groups are all rising springs. According to the gushing state of the natural spring water, it can be divided into perennial springs and seasonal springs. Historically, except for special drought years, gushing occurred basically for many years, and the cessation of spraying that often occurred after 1972 was mainly caused by the large amount of karst water mining. Therefore, the four major springs in natural conditions should be perennial springs. In recent years, the flows of the Baotu spring group and Heihu spring group have been between 25000 and 250000 m³/d, so they are large springs. The average flow of the Pearl spring group and Wulongtan spring group are mostly between 2500 and 25000 m³/d, and the monthly average flow exceeds 25000m³/d only during the high water season, so they belong to large and medium springs. The recharging sources of Jinan's four major springs are similar, and the temperature of spring water is relatively stable throughout the year, so they belong to cold water springs.
In order to protect the spring water in Jinan, it is necessary to strengthen the environmental control and protection of the spring recharge area, reasonably divide the functional area of groundwater, make use of the rain flood direct recharge area to supplement the source, control the urban expansion and optimize the layout of groundwater exploitation [5]. And we need strengthen the dynamic monitoring of groundwater, and accelerate the implementation of artificial recharge and replenishment project [6]. Scientific planning of groundwater resources should be done so as to protect the quality and quantity of spring water.

5. Conclusion

(1) Baotu spring and Heihu spring have a similar genetic structure, their circulation depth is relatively shallower, and they are greatly affected by Ordovician karst water in the direct recharging area. Tanxi spring and Pearl spring have a similar genetic structure with a deeper circulation depth, which are greatly affected by Cambrian karst water in the indirect recharging area.

(2) The four spring groups have different genetic structures. Baotu spring and Heihu spring are long-running cold springs recharged by confined water, which belong to erosion rising spring; Pearl spring and Wulongtan are long-running large and medium-sized cold springs recharged by pressurized water, which belong to contact rising spring.

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References

[1] D.X. Yuan, Karst Science in China. Geological Publishing House, Beijing, 1993.
[2] X.W. Hou, C. S. Li, L.T. Xing, Study on resource potential of monoclinic karst water system in Jinan J. China Rural Water Conservancy and hydropower.4(2014) 94-97.
[3] L.T. Xing, Q. Wu, C.H. Ye, et al, Groundwater environmental capacity and its evaluation index.J. Environmental Monitoring and Assessment.169(2010)217-227.
[4] G.H. Jiang, Y .Yu, Y. Chang, Identification of Runoff in Karst Hydrological System by Hydro-chemical Method J. Journal of Jilin University (Earth Science Edition).41(2011)1535-1541.
[5] Q.B. Meng, L.T. Xing, C.X. Teng, Study on the Relationship between "Three Waters" Transformation and Spring Water Recovery in Jinan Spring Area J. Journal of Shandong University (Engineering Science).38(2009)82-87.
[6] L.L. Liu, S.L. Song, C.M. Cui, Study on the causes of spring water in Jinan and countermeasures for spring protection, J. Shandong Water Resources .5(2013) 20-21.