Experiment and Analysis of Groundwater Tracing in Shuangfengya Tunnel of Nuoshuihe Scenic Spot

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Abstract

Taking the groundwater tracing test of Shuangfengya tunnel in Nuo Shui River Scenic Area as an example, the application of tracing test in the system analysis of karst underground river was explored. The results show that: (1) there is a hydraulic connection between the crossing point of Shuangfengya tunnel and the natural exposed point of groundwater such as the Longhu Cave in the east and the Longtingzi karst spring in the southwest. (2) There is a watershed between Longhu Cave underground river and Long Pavilion karst springs.

Keywords

Groundwater tracing; underground river; hydraulic connection; watershed.

1. Introduction

As a very effective method in the study of karst hydrogeology, groundwater tracer test is currently applied to verify the connecting relationship between the delivering point and receiving point . Meanwhile, except for being significant to expose the geometric characteristics of, spatial distribution characteristics and water flow characteristics of underground water-bearing medium, it is an important means to divide the watershed of karst groundwater, explore distribution of underground pipeline network, and research the characteristics of underground solute transport. By combining this new technology with hydrogeological conditions helps accurately figure out the connectivity of karst fissures and pipelines, as well as their spatial distribution characteristics.

2. Geological Conditions

Situating in Huitan Township, Nanjiang County, Bazhong City, Sichuan Province, the area studied belongs to the humid subtropical monsoon climate zone, where the precipitation is mostly concentrated in May-October. The 1250.7mm of average annual precipitation accounts for 78% of annual total precipitation, and the precipitation in Spring and Autumn accounts for 22% of the county. The average annual temperature is 16.2 ° C.

The major emergence stratums are middle triassic series Jialingjiang Formation (T2j), lower series Tongjiezi Formation + Feixianguan Formation (T1t + T1f), upper permian series Wujiaping Formation (P2w), lower series Maokou + Qixia Formation (P1m+ P1q), middle Ordovician Pagoda Formation (O2b), middle Cambrian Douposi Formation (∈2d) and lower series Kongmingdong Formation (∈1k), the main lithologic identifications of which are limestone and dolomite.

From the perspective of geological structure, it locates in the northern part of the Yangtze platform, the junction of the Hannan-Micangshan platform anteklise and Sichuan middle depression-north Sichuan depression, which is mainly composed of the Indosinian structural bed and Caledonian structural bed with structural trace in east-west spread.

3. Objectives and Methods of Tracer Test

3.1 Objectives of Tracer Test

The previous hydrogeological survey shows that the karst hydrogeological conditions in study area are relatively complex. The objectives of this tracer test are to (1) identify the hydraulic connection between the natural emergence points of underground water in Shuangfengya tunnel crossing area and the eastern Longhudong underground river, along with the southwestern Longtingzi karst spring, so as to determine whether there is a connecting relationship between these two. (2) To determine whether there is a watershed and groundwater flow between Longhudong underground river and Longtingzi karst spring. (3) To infer the homogeneity degree of karst water-bearing medium based on groundwater transport velocity and the concentration-time curve of tracer.

3.2 Methods of Tracer Test

3.2.1 Tracer Selection

Combined with previous tracer test experience, fluorescein sodium ($C_{20}H_{12}Na_2O_5$) is selected as the tracer considering its low natural background level; relatively low cost; high solubility in water; non-toxic, odorless and tasteless characteristics; harmlessness to local groundwater ecosystem; difficult to be absorbed by soil or surrounding rock. Meanwhile, with less precipitation and stable chemical properties, it is easily detected by instruments.

3.2.2 Selection and Distribution of Delivering Point and Receiving Point

Because the sea-level elevation of study area is 500~1900m while the survey drill ZK49+230 in the Shuangfengya tunnel is 1517 m, which is 955m higher than the outlet of Longhudong underground river and 617m above Longtingzi karst spring. The tunnel crossing area locates in the upstream recharge area of Longhedong underground river that is widely distributed in the upper permian series thick-layer limestone, where the karst is so extremely developed with several karst pipelines, so this area is equipped with experimental conditions. Therefore, the survey drill ZK49+230 in limestone area is determined as a point for tracer delivering.

According to the groundwater emergence and test purpose, the outlet of Longhudong underground river and point of Longtingzi karst spring are selected as the receiving points. The distribution and receiving points are shown in Figure 1.

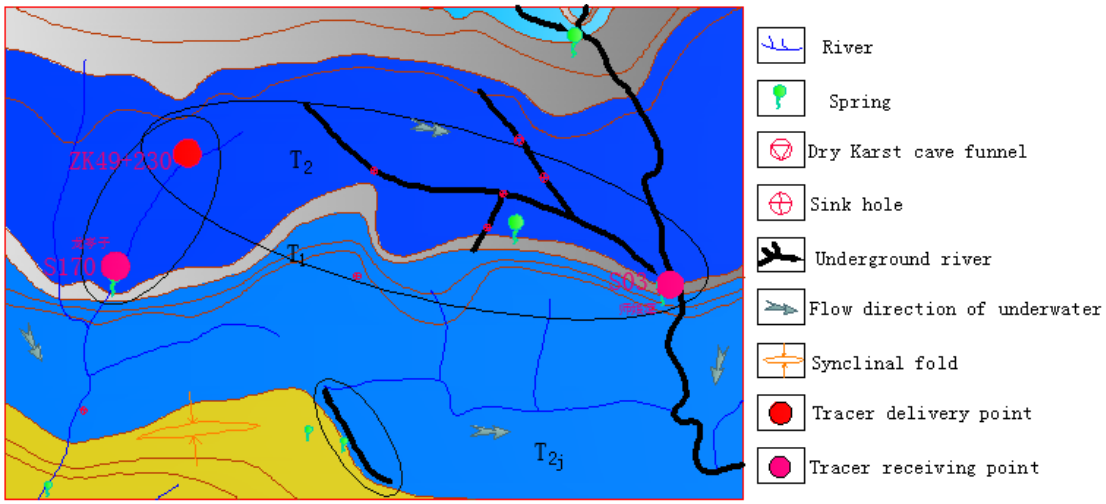

Figure 1. Position Sketch Tracer Delivering & Receiving Points

4. Process and Results of Tracer Test

4.1 Delivering and Sampling of Tracer Test

1kg of fluorescein sodium powder solid was weighed in a laboratory, sealed in a plastic bottle sealed and placed away from sunlight. In the field, this 1kg of sodium fluorescein powder was placed in a 25 L plastic bucket and then fully stirred and dissolved by adding water. A funnel was used to inject fluorescein sodium solution into the survey drill ZK49+230, and the water from side ditch was continuously pumped to the drill for 3 hours to drive the solution in drill completely into the groundwater body. The tracer was delivered at 3:00 on October 29, 2017 and the water injection ended at 6:00 p.m.

The background values of tracers in each receiving point were measured on the day before delivering the tracer. The continuous uninterrupted sampling was performed on each receiving point at 21:00 on October 29, 2017 just following the sample delivery. The initial interval was once in every 4h, later it gradually increased to once in every 2h, and finally developed to once every hour.

4.2 Detection of Tracer Samples

All of the inspections were completed in the simple indoor working area. Since the two points of in Longhudong and Longtingzi are far apart, two detection zones were set up, and fluorescein sodium was detected by two stable UV-Vis spectrometers in the same type, of which the minimum detection concentration was 0.1ppb. Considering the clear and transparent water at the sampling point, instead of placing in the dark for sediment, the detection was performed as soon as returning back to indoor area. By subtracting background value from later detection value minus will acquire the tracer concentration of sampling point.

5. Test Results and Analysis

5.1 Structural Analysis of Underground Flow Field

From the start of delivering tracer at 3:00 on October 29, 2017 to the end of sampling at 00:00 on November 5, 2017, the tracer test lasted for 8 days and 160h, during which the detection data of three sampling points was analyzed and the concentration-time curve corresponding to each sampling point was made. The concentration-time curve of Longhudong Underground River is shown in Figure 2, and the concentration-time curve of Longtingzi spring point is shown in Figure 3.

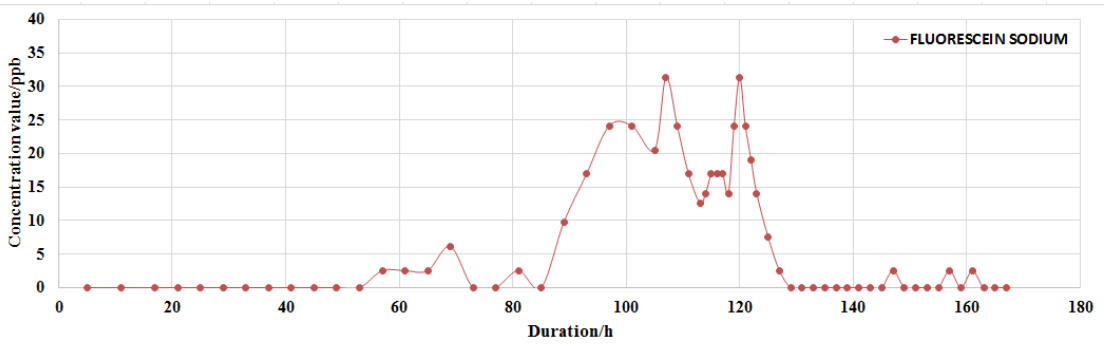

Figure 2. Concentration-Time Curve of Longhudong Underground River

The tracer concentration turned to be abnormal 57h after tracer application in receiving point of Longhudong underground river. Afterwards, the tracer detected presented sharp increase in concentration so that the maximum concentration reached to 31.3ppb. Meanwhile, the concentration-time curve showed characteristics of unimodal type which has poor symmetry, wide peak area. The duration was 72h (Figure 2). It is indicated that the underground water-bearing medium

between ZK49+230 drilling area (the tunnel crossing area) and Longhudong underground river in not uniform and there is only a single karst mainstream pipeline.

The tracer concentration turned to be abnormal 53h after tracer application in Longtingzi spring point, which quickly increased to the maximum peak after 2h continuous stroke and then a second peak appeared after some period. The maximum concentrations of the two peaks respectively were 93.5ppb and 100.7ppb, where the latter peak was slightly higher than the front peak. That is to say, the concentration presented bimodal characteristics, of which the first peak showed better symmetry and the second peak had a step-type ascending and descending feature (Figure 3). This indicated that two parallel mainstream pipelines exist between ZK147 drilling area (the tunnel crossing area) and Longtingzi karst spring point. One of the groundwater channels is single without ramp in the middle, but there may be some small dissolves or pools in the middle of the other groundwater channel, which are unevenly distributed in groundwater space.

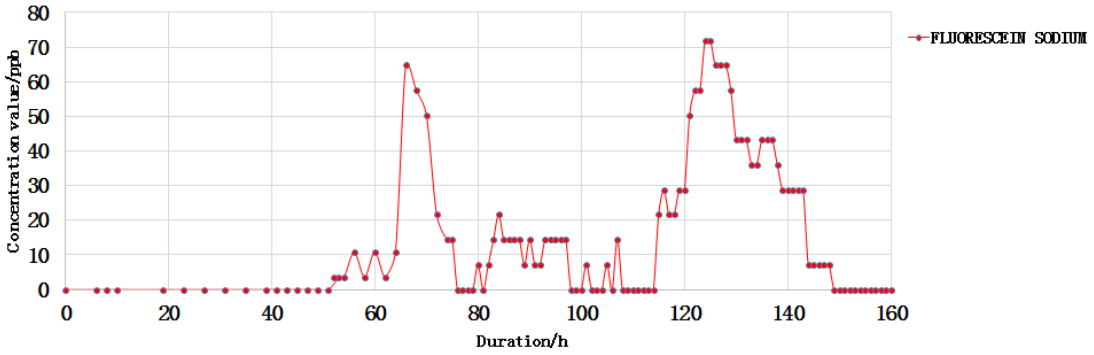

Figure 3. Concentration-Time Curve of Longtingzi Spring Point

5.2 Analysis of Groundwater Velocity

Due to the complexity and diversity of underground karst medium, the flow sate of groundwater is diversified in the process of transport. Moreover, the runoff velocity also varies for different structural characteristics of karst medium. It is generally believed that, the flow rate at the time that tracer appears is considered to be the maximum velocity of groundwater, and the flow rate at the time that peak appear indicates the average velocity.

At 20:00 on October 31, 2017, that is, 53h after the tracer application, Longtingzi began to receive the tracer and then its concentration rose rapidly until 12:00 on November 1, 2017, that is, 66h after the tracer application, the tracer concentration reached the first maximum. Afterwards, the concentration gradually decreased to the background value, and then increased sharply at 13 o'clock on November 3, 2017 after a period of stroke, that is, 115h after the tracer application. At 10:00 on November 3, 2017, that is, 124h after the tracer application, the tracer concentration reached the second maximum. On this basis, it is calculated that the maximum groundwater velocities in two underground karsk pipelines from delivery point ZK49+230 drill to the receiving point respectively are 81.13m/h and 37.39m/h, respectively, and their average flow rates are 65.15m/h and 34.68m/h, respectively.

At 3 o'clock on November 1, 2017, that is, 57h after the tracer application, the abnormal concentration of tracer was detected at the receiving point of Longhudong, which gradually increased until 5 o'clock on November 3, 2017, that is, 107h after the tracer application, reached to the peak. On this basis, it is calculated that the maximum groundwater velocity in underground karsk pipelines from delivery point ZK49+230 drill to the receiving point of Longhudong is 164.91m/h, and the average flow rate is 87.85m/h.

The straight-line distance from Longtingzi receiving point to delivery point is 4.3km, and the straight-line distance from Longhudong receiving point to delivery point is 9.4km. That means, Longtingzi receives fluorescein sodium earlier than Longhudong, but the average velocity of groundwater in Longhudong underground river pipeline is greater than that of Longtingzi underground

river pipeline. The elevation of delivery point (zk49+230 drill) is about 1517m, the elevation of Longhudong is 562m, so the relative height difference between the two points is 955m. However, the elevation of Longtingzi spring point is 900m, whose relative height difference from the delivery point is 617m. The calculation acquires that the water gradient between Longtingzi receiving point and delivery point is 0.14, which is slightly greater than the 0.10 between Longhudong receiving point and delivery point.

6. Conclusions

(1)This groundwater tracer test verified the significant hydraulic connection between the ZK49+230 drilling area and the western Longtingzi karst spring, along with the eastern Longhudong underground river.

(2)The analysis of the tracer concentration-time curve finds that there are at least two karst pipelines developed between the Longtingzi and receiving point. If there are only two karst pipelines, they may exist in parallel. On the other hand, there is only one karst pipeline between Longhudong underground river and the receiving point without ramp in the middle.

(3)Combined with the results of tracer test and comprehensive analysis of actual geological survey, one part of the groundwater in the limestone of ZK49+230 drilling area mainly flows toward the southwest and is discharged outward through Longtingzi karst spring; the other part flows toward the southeast and is discharged outward through Longtingzi karst spring. It can be learned that there is a watershed between Longhedong underground river and Longtingzi spring, which is nearby ZK49+230 drilling area .

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