Study on dynamic relationship of spring water in Jinan spring area based on gray relational analysis

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Abstract. Springs Jinan to spring sparks spectacular and famous at home and abroad. With the development of the city and the increase of the amount of groundwater, the gas inflow of Jinan spring group in the late 1960s has been declining. In the early 1970s, Baotu Spring has dried up in the dry season. Since then, the spring water in most years has been cut off and the drying time Growing. In recent years, under the leadership of the provincial and municipal governments, through the joint efforts of various departments and in the extreme conditions of precipitation, making Jinan spring has been spewing more than 4 years. In this paper, the changes of groundwater level fluctuation in the western part of Jinan and the urban area in Jinan in 2015 are analyzed. The gray relational analysis method is used to study the fluctuation of groundwater in the west of Jinan and the spring area of Jinan City. Through the calculation of the correlation degree, it is found that the mean value of the correlation between the groundwater level of the monitoring wells and the water level of the spring water in the urban area is 0.7738. This data indicates a higher degree of correlation. Thus, the amount of groundwater in Jixi and Jinan City is illustrated by the presence of hydraulic connections. But to protect the famous spring spewing, reproduce the natural landscape of water and build a harmonious water city, this ambitious goal is still good and fast development process in Jinan, a subject.

1. Introduction
Jinan karst aquifer is a complex groundwater system, precipitation and river water as the main source of supply, the city center spring group as an important drainage point. Karst water is an important source of water for production, living and ecological landscape in Jinan. In recent decades, the continuous increase of utilization of groundwater resources has led to the drop of karst water level in Jinan and threatened the fountainheads in urban areas. It is an important way to restore the ecological environment of spring water through artificial recharge to increase aquifer recharge [1].

The Yufu River is an important source of supply for Jinan Springs water. At the outset of the Yufu River, the riverbed passes through the Cambrian-Ordovician system and supplies urban springs. In 2001 and 2002, water was discharged twice to the Yufu River and groundwater recharged through
river infiltration. The results of water level observation show that the spring water level in an urban area has a consistent response to the change of river water level, and the river bed leakage recharge should be an important source of water supply for groundwater [2].

Based on the fluctuation amplitude of groundwater level, the gray relational analysis method is used to calculate the correlation degree between the groundwater level of each monitoring well in Jinan Western and the springs in the urban area by the calculation of the amplitude correlation degree [3]. The higher the correlation is The stronger nature, further from the amount that the western Jinan and Jinan spring groundwater recharge and drainage relations.

2. Research Area Overview
Jinan is located in central Shandong Province, in South Shandong hilly and northwest transition onto the alluvial plain, low-lying South high north. The types of aquifers with water supply in the study area are Quaternary pore aquifer and Cambrian-Ordovician aquifer. The Quaternary pore water is located in the Yufu River and the BeiDa Shahe alluvial fan. The water level is buried at a depth of 20-70 m with an aquifer thickness of 10-30 m. The water is rich in water and has a large single well water volume. The Cambrian-Ordovician fractured karst water is controlled by the topography, lithology and tectonic factors, and is rich in fractured karst where connectivity is good. The recharge source is atmospheric precipitation and river water, Runoff and artificial mining excretion [4].

Jinan Yufu River basin water recharge project, the purpose is to the Yellow River water (from Yuqing reservoir and Tian Shan electric pumping station) and Wohushan reservoir water, the pumping station to lift water or reservoir drainage [5]. The surface water is transformed into karst groundwater by the strong osmosis of the upstream channel of Yufu River. Jinan Western, Cold village, Qiaozili village, Mount Emei, Dayang village, mountain water source, has the best conditions of exploitation of karst water. Provide high-quality drinking groundwater for Jinan City, and to a certain extent, increase the amount of spring water recharge.

According to the relevant experts in spring protection, since April each year, the provincial capital precipitation more, and five reservoir connectivity project also played a spring protection benefits, so that the spring water level has maintained a certain period of stability [6]. In addition, Jinan City, Water Policing Team has maintained a high pressure on water law enforcement, the implementation of the most stringent groundwater management, to minimize the exploitation of groundwater.

3. Research methods

3.1. Gray correlation analysis of the basic ideas
Gray relational degree is a kind of method in gray mathematics, which is used to study the influence of complicated factors of things interrelated and interaction, to determine the essential factors that affect things and to clarify the "gray" relationship among various influencing factors. This paper introduces the analysis methods and steps of a gray relational degree in practical work, which provides a theoretical basis for the quantitative description of the mutual change between things or factors.

Relevance is a measure of the magnitude of the relationship between things and factors. It quantitatively describes the change of things or factors between the situation, that is, the size of the change, the direction and speed of the relativity. If things or factors change in the same direction, you can think that the correlation between them is larger, on the contrary, less relevant. Although this kind of relationship between things or factors can be answered to some extent by regression, correlation and other statistical analysis methods, it often requires a large amount of data and the data distribution characteristics are also more obvious. And for the phenomenon of multifactorial atypical distribution, regression analysis is often difficult. Relatively speaking, gray correlation analysis requires less data, fewer data requirements, the principle is simple, easy to understand and grasp, to overcome the above deficiencies and makeup. The core of gray relational analysis is calculating the degree of correlation. Generally speaking, the calculation of the degree of correlation must first deal with the original data and then calculate the correlation coefficient, from which we can calculate the degree of association.
3.2. Gray correlation degree
Polyline Sequence Expressions
Let sequence \( X_i = (x_i(1), x_i(2), \ldots, x_i(i), \ldots, x_i(n)) \), \( 1 < i < n \), then the function of the fold line \( L_1 \) corresponding to the sequence \( X_1 \) is where:

\[
y_1 = x_1(k) + (m - k) \cdot \left[ x_1(k+1) - x_1(k) \right]; \quad k = 1, 2, \ldots, n-1; \quad k \leq m \leq k + 1;
\]

Thus the sequence \( X_j = (x_j(1), x_j(2), \ldots, x_j(i), \ldots, x_j(n)) \), \( 1 < j < n \); then the line corresponding to the sequence \( X_j \) is \( L_j \). The expression is:

\[
y_j = x_j(k) + (m - k) \cdot \left[ x_j(k+1) - x_j(k) \right]; \quad k = 1, 2, \ldots, n-1; \quad k \leq m \leq k + 1;
\]

Polyline sequence amplitude
Amplitude is:

\[
A_1(i, i+1) = y_{i+1} - y_i = \Delta y_1(i)
\]

Where: \( A_1(i, i+1) \) and \( \Delta y_1(i) \) are the water level amplitudes, and \( y_{i+1} \) is the ordinate of the line \( L_1(i, i+1) \).

Similarly, the amplitude of the polyline \( L_j(i, i+1) \) is:

\[
A_j(i, i+1) = y_{i+1} - y_i = \Delta y_j(i)
\]

Polyline coordinate and amplitude of the relationship shown in Figure 1.

![Figure 1 Water level fluctuation amplitude](image)

Water level fluctuation amplitude correlation coefficient and correlation degree
For waveform 1 and waveform J, the amplitude correlation coefficient of the Mth wave is:

\[
R_{1,j}(m) = \sgn\left(A_1(m), A_j(m)\right) \cdot \frac{1 + |A_1(m)| + |A_j(m)|}{1 + |A_1(m)| + |A_j(m)| + |A_1(m)| - |A_j(m)|}
\]

\[
\sgn(A_1(m), A_2(m)) = \begin{cases} 
1 & (A_1(m) * A_2(m)) \geq 0 \\
-1 & (A_1(m) * A_2(m)) < 0 
\end{cases}
\]

The correlation degree between waveform 1 and waveform J is:

\[
\gamma_{1,j} = \frac{1}{n} \sum_{m=1}^{n} R_{1,j}(m)
\]

3.3. Gray correlation degree
In 2015, monthly average groundwater level data of some monitoring wells in western Jinan and urban springs, By using the gray relational method, the monthly amplitude of water level is calculated first,
then the monthly amplitude correlation coefficient is calculated, and finally, the gray amplitude correlation degree is obtained from the correlation coefficient. Amplitude correlation. The magnitude of the correlation degree is compared to analyze whether there is a hydraulic connection between the groundwater in western Jinan and urban springs. The data of groundwater table of monitoring wells in western Jinan and urban Spring regions in 2015 are shown in Table 1 and Fig. 2.

**Table 1.** 2015 The average groundwater level in each of the monitoring wells in urban Spring region and Jinan Western (Unit: m)

| Date            | Du Temple Village | Zhu Village | South Bali village | Basket in the village | Baotu Spring | Black Tiger Spring |
|-----------------|-------------------|-------------|--------------------|-----------------------|--------------|-------------------|
| December 2014   | 28.545            | 29.503      | 28.701             | 29.261                | 27.989       | 27.899            |
| January 2015    | 28.501            | 29.438      | 28.622             | 29.212                | 27.847       | 27.764            |
| February 2015   | 28.681            | 29.438      | 28.622             | 29.212                | 27.877       | 27.800            |
| March 2015      | 28.681            | 29.438      | 28.309             | 28.801                | 27.822       | 27.746            |
| April 2015      | 28.102            | 29.065      | 28.438             | 28.828                | 27.738       | 27.668            |
| May 2015        | 28.242            | 29.138      | 28.437             | 28.976                | 27.824       | 27.755            |
| June 2015       | 27.498            | 27.642      | 27.615             | 28.261                | 27.427       | 27.367            |
| July 2015       | 27.523            | 28.555      | 27.700             | 28.282                | 27.497       | 27.435            |
| August 2015     | 28.314            | 29.301      | 28.590             | 28.820                | 27.997       | 27.934            |
| September 2015  | 28.535            | 29.434      | 28.934             | 29.203                | 28.219       | 28.157            |
| October 2015    | 28.130            | 27.788      | 28.481             | 28.914                | 27.925       | 27.856            |
| November 2015   | 28.654            | 28.709      | 28.631             | 29.571                | 27.933       | 27.865            |
| December 2015   | 28.998            | 28.991      | 28.971             | 29.901                | 28.050       | 27.989            |

**Figure 2.** Dynamic change of groundwater level for 2015

It can be seen from Figure 2 that the dynamic changes of groundwater level in Du Temple Village, Zhu Village, South Bali village, Basket in the village and other places in the west of Jinan City are basically the same as those of urban spring groundwater table, and the groundwater table in Jinan western to be higher than the urban springs water level [7]. May-July groundwater level is low. In 2015, the amplitudes of monthly average groundwater table fluctuation in monitoring wells in Jinan western and urban Spring regions were analyzed. The gray relational method was used to analyze the data, and the correlation coefficient and correlation degree were calculated respectively in table 2.
Table 2. 2015 The correlation coefficient and correlation degree of groundwater amplitude in the west of Jinan and urban Spring regions

| Jinan Western | Du Temple Village | Zhu Village | South Bali village | Basket in the village |
|---------------|-------------------|-------------|--------------------|-----------------------|
| Jinan spring  |                   |             |                    |                       |
| Baotu Spring  | 0.8960            | 0.8507      | 0.5970             | 0.7512                |
| Black Tiger Spring | 0.8970    | 0.8507      | 0.5975             | 0.7502                |
| Average value | 0.8965            | 0.8507      | 0.5973             | 0.7507                |

4. The analysis of the results and discussion

According to the calculation results of gray amplitude correlation degree, Du Temple Village and Baotu Spring, Black Tiger Spring has the highest amplitude correlation. The degree of association is 0.896 and 0.8970 respectively. The grey correlation degree is high, showing good correlation. The calculation of correlation degree quantitatively reflects the groundwater in places like Du Temple Village, Zhu Village, South Bali village, Basket in the village in western Jinan. Analysis of the correlation between Jinan western groundwater and Baotu Spring, Black Tiger Spring groundwater in the urban area. Baotu Spring and Black Tiger Spring and Jinan western around the degree of correlation almost coincide curve, and the average correlation of 0.7738, a higher degree of relevance, a strong correlation.

In order to achieve the goal of continuous spewing of Jinan spring water, the layout of groundwater exploitation should be adjusted, the amount of recharge groundwater in the west of Jinan should be appropriately increased, and surface water should be used to recharge karst groundwater in strong leakage areas such as Yufu river and Beidasha river[8][9]. Efficient groundwater recharge, scientific protection of urban springs in Jinan.

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