Correlation analysis of mid-deep groundwater chemical composition of Weibei Plain

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Abstract. The freshwater and brackish water in the mid-deep layers of Weibei Plain plays an important role in the development of the local economy. This paper uses statistical theory such as principal component analysis, correlation analysis, and stepwise regression to analyze the chemical composition of middle and deep groundwater of Weibei Plain to find the main indicator ions that affect TDS.

1. Introduction
The mid-deep freshwater and brackish water of Weibei Plain plays an important role in the local economic development. Studying the groundwater chemical composition and finding the main influencing factors of TDS has an important effect in monitoring water quality and can further guide the rational development and utilization of groundwater.

2. Distribution characteristics of freshwater and brackish water in the mid-deep layers of Weibei Plain
The loose layer in Weibei Plain is thicker, and the area is dominated by the exploitation of pore water of loose rocks. The chemical characteristics of groundwater in the area have obvious horizontal and vertical zoning. The mid-deep aquifers are mainly composed of alluvial and volcanic genesis in the southern mountainous area and loose sediments in the Taihang mountainous area. According to the age of the aquifer formation, it is divided into Quaternary loose rock pore water and Neogene loose rock pore water, and the TDS is less than 1.5g / L—Figure 1.
3. Sample distribution
The sample data volume of this paper is 531. The target horizon is mid-deep groundwater. The TDS value is relatively affected by the sea (salty) water, and most of them are brackish water.

4. Correlation analysis of water chemical composition

4.1 Data processing
Before the statistical analysis of the data, we use the average value filling method to obtain the average value from the object with the same decision attribute value as the object to fill the missing data. In this paper, we use statistical correlation theory to analyze the correlation of chemical components in the mid-deep groundwater of Weibei Plain. Correlation analysis of each ion and TDS was performed and a linear regression equation was fitted to explore the influence intensity of the main influencing ions on the total TDS in the mid-deep groundwater of Weibei Plain.

4.2 Pearson correlation analysis
First, we analyze the correlation of each ion and TDS, and use the Pearson correlation coefficient to conduct a two-sided test (Table 1 lists the factors that are highly correlated with TDS). The correlation
with TDS is Na⁺, K⁺, SO₄²⁻, Mg²⁺ in descending order, the coefficients are all greater than 0.8, followed by Ca²⁺, the coefficient is 0.68, and the p values are close to 0, which is very significant.

| Ions            | Na⁺   | K⁺    | Ca²⁺  | Mg²⁺  | NH₄⁺  | SO₄²⁻ |
|-----------------|-------|-------|-------|-------|-------|-------|
| Correlation coefficient | 0.935 | 0.941 | 0.683 | 0.858 | 0.154 | 0.884 |
| p value         | 0.000 | 0.000 | 0.000 | 0.000 | 0.032 | 0.000 |

### 4.3 Stepwise regression

In order to further clarify the influence of each ion on TDS, we use stepwise regression method to fit the relationship between each ions and TDS to get a more accurate measurement result. We use various water chemical components as independent variables, and TDS as the dependent variable. By fitting the data, we get the TDS influence factor equation as in equation (1):

\[
TDS = 2.51Na^+ + 4.35Mg^{2+} + 0.55SO_4^{2-} + 1.97NO_3^- 
\]

(1)

The indicator cation of TDS in the mid- deep groundwater of Weibei Plain is Mg²⁺, and the anion is NO₃⁻.

| Ions | Correlation coefficient | t statistic | p value |
|------|-------------------------|-------------|---------|
| Intercept | -8.07          | -0.39       | 0.70    |
| Na⁺   | 2.51             | 26.09       | 0.00    |
| Mg²⁺  | 4.35             | 8.12        | 0.00    |
| SO₄²⁻ | 0.55             | 4.21        | 0.00    |
| NO₃⁻  | 1.97             | 2.30        | 0.03    |

### 4.4 Principal Component Analysis

We use principal component analysis to analyze the influence level of various ions to chemical composition of groundwater in the mid-deep layers of the area and extract two major components (Figure 2, Table 3) with large effects. The first principal component F1 mainly contains Na⁺, K⁺, Ca²⁺, Mg²⁺, Cl⁻, SO₄²⁻ ions, are closely related to the intrusion of sea (salty) water in this area; the second principal component F2 mainly contains NH₄⁺ and F⁻ ions, less affected than F1 significantly. The background value of F⁻ in the area is relatively high, and ammonia nitrogen has a greater impact on groundwater during crop planting and mariculture in this area.
Figure 2. Scree plot of the main component of the mid-deep groundwater of Weibei Plain.

Table 3. Analysis of main components in the mid-deep groundwater of Weibei Plain.

| Elements | F1     | F2     | Elements | F1     | F2     |
|----------|--------|--------|----------|--------|--------|
| K        | 0.979  | 0.047  | Cl       | 0.985  | 0.051  |
| Na       | 0.984  | 0.058  | SO$_4$   | 0.980  | 0.003  |
| Ca       | 0.853  | -0.263 | CO$_3$   | -0.109 | 0.552  |
| Mg       | 0.980  | 0.009  | F        | -0.134 | 0.782  |
| NH$_4$   | 0.144  | 0.708  | NO$_3$   | -0.006 | -0.498 |
| Fe       | -0.068 | 0.623  | NO$_2$   | -0.005 | -0.009 |
| Mn       | 0.705  | 0.050  |          |        |        |

5. Conclusion
In summary, the main indicator cations of TDS in the mid-deep groundwater of Weibei Plain are Mg$^{2+}$, Na$^+$, and the main indicator anions are NO$_3^-$ and SO$_4^{2-}$.

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