

## Estimation of Hydraulic Relationship of Keyno Anticlines in North of Khuzestan Province Using Hydrochemical Data, Basic Component Analysis (PCA) and Hierarchical Cluster (HCA)

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### 1-Introduction

Groundwater is one of the most important sources of drinking water, agriculture and industry around the world, and its importance is increasing due to population growth and climate change. The process of reducing groundwater quality has created challenging conditions for human action, which is continuously expanding. Therefore, it is necessary to monitor and study these resources for the conservation, maintenance, and improvement of its quality and quantity (Adepelumi et al., 2009). One of the essential tasks in the management of groundwater resources is the recognition of the hydrogeochemical processes governing the aquifer system. The result of this process is the formation of a chemical composition of groundwater which is controlled by several factors, such as the chemical composition of rainwater, human activities, geological and mineralogical structures of the basin and aquifer (Andre et al., 2005; Gibbs, 1970). One of the most suitable methods for recognizing the processes governing the chemical composition of groundwater is the use of descriptive charts such as Piper, Gibbs, and hybrid graphs in hydrogeochemistry. Although these graphical methods are used to evaluate the processes governing groundwater, they are also subject to shortcomings. Some non-chemical parameters such as nitrate, silica, arsenic, fluorine may also be used, as well as non-chemical parameters such as temperature and viscosity (Voudouris et al., 2000). Also, geological and hydrogeological processes are complex, and these complexities do not directly indicate the rules governing processes. Therefore, it is not possible to study the quality of groundwater with complicated hydrogeological conditions using graphical methods (Banoeng-Yakubo et al., 2009). Using methods such as tracing and hydrochemistry due to high costs is only suitable for projects with a lot of economic resources. Therefore, one of the applied methods in this field is the use of multivariate statistical methods (principal component analysis and hierarchical cluster analysis) that has been considered for the determination of the relationship between different hydrological, hydrogeological and hydrodynamic data of aquifers, for example, Mohamadi et al. (2009) Khosravi et al. (2015), Guler et al. (2002).

The purpose of this study was to investigate the changes in the chemical parameters of the keyno anticline carbonate springs and the correlation of these changes by investigating the relationship between these springs with multivariate statistics (principal factor analysis and hierarchical clustering). In the anticline of Keyno, there are eleven springs reported among which, with an attitude to the available data for the springs of Susan, Tangsard, Absardeh, and Mori for research, have been selected.

### 2-Methodology

In this study, four spring springs (Susan S1, Tangsard S2, Absardeh S3, and Mori S4) have been used to assess the quality of water data of all four springs during the period from December to July 2009. This information is about the physicochemical parameters of water, K<sup>+</sup>, Ca<sup>2+</sup>, TDS, EC, Cl<sup>-</sup>, Mg<sup>2+</sup>, HCO<sub>3</sub><sup>-</sup>, SO<sub>4</sub><sup>2-</sup>, Na<sup>+</sup>. Before statistical analysis, the first heterogeneous data were removed using the nearest neighbor method, and then logarithm was used to reduce the effect of the difference in the scale of the data. Multivariate statistical studies and data analysis using XLSTAT2016 software. The interpretation and determination of the origin of each of the factors have been done based on factor loads, hydrological conditions, geological conditions, and hydrochemical processes. Then, for further investigation, classical

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hydrodynamic methods such as graphics methods and ion ratios are used. In the field of multivariate statistical analysis, the data were standardized using the PCA method in the XLSTAT software environment using the logarithmic method. In the next step, KMI (Kaiser-Meyer-Olkin) test assessed the use of factor analysis for the statistical population. Given the minimum of 0.5 for the KMO coefficient for the competence of using the functional test, the values of this coefficient were examined (Table 1). The results of this study show the suitability of the hydrochemical parameters for the analysis, Shokouhifar, and Izadpanah (2013). Varimax rotation was used to improve the relationships between inputs and primary factors and their better separation for membership.

**Table 1. The adequacy of the hydrodynamic data of the studied springs with the KMO method**

Kaiser- Meyer-Olkin	
.682	S1
.62	S2
.659	S3
.702	S4

### 3-Results and discussions

#### 3-1 Correlation between variables

In this research, the principal component analysis is based on the correlation matrix, because a careful study of the correlation matrix can show the relationship between the variables as well as the relationship of the data set with each other. (Oinam et al. 2012). The correlation matrix showed that the highest correlation was between chlorine and sodium (0.998), sodium and EC (0.904), bicarbonate and magnesium (0.691), bicarbonate and EC (0.616), and Sulfate and calcium (0.779).

#### 3-2 Extraction of main factor loads

In this research, factor loadings with individual values of more than one considered as the main components affecting the chemical quality of the Keyno anticline springs. Thus, the qualitative parameters divided into ten components, each of which has a particular value with varying degree of variation and cumulative variability. The results show that the first and second components have the most qualitative changes (respectively, 47.69 and 23.95, respectively). Therefore, the first and second components selected as the best factor in describing water quality changes in the studied springs. Thus, in the first component (D1), the parameters of magnesium, sodium, bicarbonate, chlorine, TDS, EC, with cosine square 0.460, 0.666, 0.382, 0.65, 0.884 and 0.494 respectively. It is important to attribute this factor to the high correlation between magnesium and bicarbonate, due to the high correlation between sodium and chlorine can be attributed to the dissolution of halite and also the dissolution of dolomite. In the second factor (D2), calcium and sulfate show the highest correlation with the cosine of 0.759 and 0.049, respectively, indicating the dissolution of evaporative minerals such as anhydrite.

#### 3-3 Hierarchical cluster analysis (HCA)

Based on the hierarchical clustering method, observations within a class (within the group) have a zero-level variance, and there is no significant difference between these groups. Therefore, their origin is the same. Those observations that are outside of the groups (Between group) have maximal variances, Farshadfar,(2009). With the view of observation data (springs) located in the horizontal axis (Fig. 1), it is determined that the Susan spring (S1) and the Tangsard (S2) form a cluster and Absardeh and Mori spring also form another cluster. Clustering can be due to the same origin of the Susan Springs (S1) and Tangsard (S2) and the same origins of the Springs (S3) and Mori (S4).

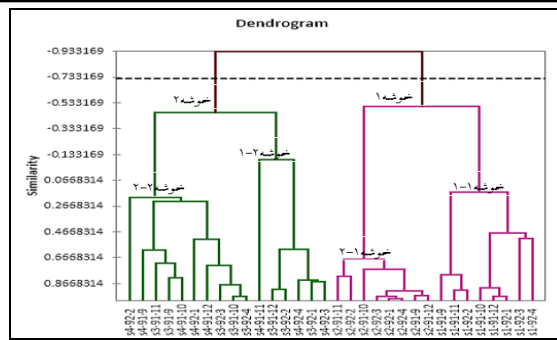


Figure 1. Time-spatial clustering of the Keyno Springs data in Q-mode clustering.

#### 3-4 Investigating the geochemical processes governing the Keyno anticline springs

For a closer examination of the chemical processes governing the Kinoy anticline springs and their origin, R-mode mode from hierarchical clustering, Piper diagram and ion ratio were used. Dendrogram of hydrochemical data for hierarchical clustering in R-mode mode for the studied springs showed two clusters for the data used. That first class consists of two main clusters. The first main cluster includes sub-cluster of sodium, chlorine, TDS, and EC and indicates the contact of springs with evaporite of Kalhor in Asmari Formation and Ilam Sarvak marl formation. Under the second cluster, it contains bicarbonate and magnesium; this cluster is the result of the dissolution of the Ilam-Sarvak lime and the intermediate layers of the Asmari Formation. The second main cluster contains sulfate and calcium elements. Geological studies carried out in the study area revealed that there are no gypsiferous outcrops in these areas. Therefore, this cluster could indicate the contact between the Susan and Tangsard fountains with the Gurpi Formation and the Gothenia Foghinia Formation located below the Gora Formation.

The results of the plotting of the Piper diagram show that most samples of the S1-S2 springs contain bicarbonate, calcium and some high magnesium. Most S3-S4 springs samples contain calcium, bicarbonate, sodium, and chlorine. By plotting the Piper chart, in addition to the water type, it can be seen that the springs S1-S2 and S3-S4 are accumulated in one part of the diagram, which can indicate the same origin of the S1 and S2 springs as well as the S3 and S4 springs together. The calculated ratios for the studied springs have shown that the mean Ca / Mg ratio in the lilies, tangsard, depressed and mori springs is 3.39, 3.85, 2.38, and 1.87, respectively.

#### 4-Conclusions

The results of multivariable statistics (PCA, hierarchical cluster analysis (HCA)) and the study of the geochemical processes governing the springs have shown that two Susan spring and Tangsard spring with each other and also, Absardeh spring and Mori spring have hydraulic connectivity.

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