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Multivariate Statistical Analysis of the Hydro-Chemical Groundwater Quality in Lour Plain, Khouzestan, Iran

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ABSTRACT: Multivariate statistical techniques, such as principal component analysis was performed on 31 wells reprehensive groundwater samples gathered from different tributaries of Dezful plain , North Khouzestan, Iran. Application of statistical analysis of the data helps us to understand the hidden relationship between ions. Correlation analysis and factor analysis were applied to classify the groundwater samples. The collected samples were analyzed for a total of 10 water quality variables including: total dissolved solids (TDS), electrical conductivity (EC), total hardness (TH), Calcium (Ca^{2+}), Magnesium (Mg^{2+}), Sodium (Na^{+}), Chloride (Cl^{-}), and Bicarbonate (HCO_3^{-}). Principal component analysis (PCA) was utilized to reflect those chemical data with the greatest correlation. By utilizing PCA, the identified two major principal components (PCS) representing almost 77 percent of cumulative variance were able to interpret the most information contained in the data. PC 1 reflects the dominance of salinization, which was characterized by the elevated concentrations of EC, chloride, sulfate, total dissolved solid and magnesium in groundwater.

***Keywords*:** Groundwater, Multivariate Analysis, Principal Component analysis.

INTRODUCTION

In arid and semi- arid regions, groundwater is an important part of the total water resources, and are limited in agriculture and water resources. Farmers are deep depending on groundwater. Iran is limited in agriculture and surface water. Lur plain is one of the most important agricultural activities in southwest of Iran and groundwater is the main source of potable water of Dezful plain. Because the lack of precipitation, the use of groundwater resource is crucial. Use of groundwater for long time resulting of water level decrease and increasing groundwater salinity. The rapid industrialization, urbanization and agricultural development cause high pressure on groundwater resources. Multivariate statistical analysis consists of a number of statistical methods. Multivariate statistical techniques were used to interpret complex data matrices to better understand the water quality and ecological status of the studied system. These methods are also giving a better understanding of the chemical properties of the groundwater system (Subbarao et al., 2001).

MATERIALS AND METHODS

Study Area

The study area lies down between at longitude 48° 9′ and 48° 47′ East and 32° 2′ and 32° 36′North in South west Iran and covers total area of 295 Km^2. Agriculture is main activity of the people of the area. Average rainfall is nearly 346 mm, during 2013.

All underground water samples are collected from wells in different parts of study area during June 2013 and analysis for their chemistry. The samples collected were analyzed for major cation like, Ca^{2}+ and Mg by Titrimetry, Na^{+} and K^{+} by Flam photometer , anions, Cl^{-} and $HCO3^{-}$ by Titrimetry , SO_4^{2-} by Turbidimetry, EC and p H were determined in the field using electrode. TDS was measured in situ by TDS portable electrode model Sension 378. The analyses were done by adopting standard procedures (APHA, 1995). The average temperature at the time of sampling was 45° C.

Data analysis

The multivariate statistical analysis is a quantitative and independent approach of groundwater classification allows group of groundwater samples and making of correlations between chemical parameters and groundwater samples. In this correlation analysis and factor analysis were applied using Statistical Package of Social Studies (SPSS) version 17.

Table 1. Maximum, Minimum, average and standard deviation for chemical composition of groundwater (in meq/L) except (in µS/cm) and pH

	Summer-2013			
	Max	Min	Avg	Std
p H	8	7	7.9	0.38
EC	830	235	491	192.8
Cl	2	0.31	1	0.48
HCO3	3.51	1.8	2.62	0.51
SO4	3.46	0.02	1.29	1.138
Ca	3.8	0.1	2.18	1.08
Mg	2.58	0.33	1.46	0.78
Na	3.17	0.09	1.73	0.93
K	0.03	0.01	0.027	0.007
TDS	500	142	312.8	121.9

Hydro-chemical characteristics

The chemical composition of the groundwater samples were statistically analyzed and the obtained in results are summarized Table 1. EC values of the groundwater samples of the studied area ranged from 245 to 1190 µS/Cm and pH values varied from 7.2 to 8.2 indicating that the water was slightly alkaline during summer. The total dissolved solids (TDS) ranged from 189- 741 mg/L. According to Table 1 it is clearly observed that the order of abundance of the major ions in groundwater is in the following order: Ca^{2+}> Mg^{2+}> Na^{+}> K^{+} and SO_4^{2+}> HCO_3^{-} > Cl^{-}> K^{+} .

Correlation of physicochemical parameters of groundwater

Correlation coefficient is a commonly used measure to establish the relationship between two variables. The correlation matrices for 10 variables were prepared for July 2013 (Table 2) and illustrate that EC and TDS show good positive correlation with Mg^{2+} and HCO_3^{-} . TDS and Mg^{2+} also exhibit high positive correlation with SO_4^{2-} and HCO_3^{-} ions, respectively, during July 2013. EC- SO_4^{2-}, TDS- SO_4^{2-} , TDS- Mg^{2+}, Mg^{2+}- SO_4^{2-}, Mg^{2+}- HCO_3^{-}, Cl^{-} - Na^{+} are also the more significant correlation pairs during July 2013.

Table 2. Correlation of physicochemical parameters of groundwater of July 2013

	EC	TDS	p H	Cl	SO4	Na	HCO3	Mg	Ca	K
EC	1									
TDS	0.891	1								
p H	-0.584	-0.51	1							
Cl	0.763	0.859	-0.4	1						
SO4	0.834	0.938	-0.6	0.657	1					
Na	0.783	0.757	-0.5	0.802	0.633	1				
HCO3	0.784	0.878	-0.5	0.789	745	0.676	1			
Mg	0.819	0.919	-0.5	0.731	0.87	0.579	0.923	1		
Ca	0.624	0.483	-0.1	0.367	0.459	0.451	0.29	0.371	1	
K	0.438	0.469	-1.8	0.436	0.397	0.345	0.467	0.484	0.452	1

Statistical analysis By multivariate analytical techniques, the obtained groundwater data can be simplified, organized and generalized to bring about useful meaning. Principal component analysis (PCA) is known as a

powerful technique of data reduction based upon analysis of the correlation or covariance matrix within large sets of data (Farnham et al., 2003).

RESULTS AND DISCUSSION

Principal component analysis PCA has been applied to both variables and samples corresponding to sampling from thirty – one wells in 2013. As mentioned, PCA is based on diagonalization of the correlation matrix that can give the overall coherence of data set. We can observe strong and positive correlations: chloride and sodium (r = 0.802), total dissolve solid and magnesium (r = 0.919), Magnesium and sulfate (r = 0.87), electrical conductivity and sulfate (r = 0.834), total dissolve solid and sulfate (r = 0.938), magnesium and bicarbonate (r = 0.923). The Kaiser- Meyer – Oklin test carried out on the correlation matrix shows a calculated value KMO = 0.707 greater than the acceptable value 0.5, thus meaning tht PCA can successfully reduce the dimensionality of the original data set. PCA results including the rotated loading, eigenvalues, and variance percentage of each PC are summarized in table 1. A screed plot was commonly used to identify the number of factors be retained for acquiring adequate information, which shows a change of slope after the two eigenvalue. The obtained two PC_S have eigenvalues greater than unity and explain 79.61% of the variance or information contained in the original data set. The absolute value of the loadings greater than 0.7 are highlighted in Table 1 because it is an indicator of the participation of the variables in the PC_S. PC1 accounts for 64.74% of the total variance and is characterized by very high loadings of EC, sulfate, bicarbonate, magnesium and chloride. PC 2 explains 11.87% of the total variance and is mainly associated with very low loadings of variable.

Table 3. varimax rotated component Mtrix in PCA analysis

Variable	Factor 1	Factor 2
Mg	0.945	0.105
TDS	0.93	0.305
HCO3	0.924	0.118
SO4	0.884	0.22
EC	0.837	0.436
Cl	0.749	0.434
Na	0.629	0.646
Ca	0.322	0.584
K	0.034	-0.894
pH	-0.625	-0.116
eigenvalue	6.47	1.18
Variance (%)	64.74	1.187
cumlative Variance	64.74	76.61

Magnesium plays a main role in determining hardness, thus the presence of this cation in groundwater results in the enhancement of hardness and a strong positive correlation of EC with sulfate, chloride, magnesium. PC 1 is accordingly defined as the salinization factor.

CONCULSION

This study has successfully demonstrated the utility multivariate statistical analysis to characterized groundwater quality. In our case, PCA explains 76.61% of total variance and recognizes two PC_S as salinization. By the aid of statistics techniques it is predictable to be aware of the underlying processes and the distribution of sources that might affect groundwater quality.

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