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Multivariate Statistical Analysis of Groundwater Quality in Wadi Ranyah, Saudi Arabia

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Abstract. Multivariate statistical techniques, such as cluster analysis and principal component analysis were performed on 22 well-representative groundwater samples gathered from different tributaries of Wadi Ranyah, Western Provence, Saudi Arabia. The collected samples were analyzed for a total of 21 water quality descriptors (variables) including major and trace elements. From traditional Durov diagram water classification, the water quality is Calcium-Bicarbonate type. In addition, saturation indices (SI) were calculated for Anhydrite, Gypsum and Halite and the results show that the water is under-saturation state. R-mode cluster analysis resulted in two distinctive sources controlling water chemistry: groundwater-rock interaction, agriculture and anthropogenic sources. The first three principle components explained 70% of the total data variability. First factor reveals strong associations between Ca^{2+}, Mg^{+}, Na^{+}, HCO_3^{-}, SO_4^{2-}, pH , TH and conductivity and trace elements as PO_4^{3-} and SiO_2. The second factor represents the high loading of NO_3^{-} and Mn^{+} as the input of soil water. The third factor reveals high loading of Chloride (Cl^{-}) which may be due to the flushing of evaporate minerals with recent rainfall recharge. Plots of samples of F1 versus F2 show approximately one group with good separation of outlier samples, where F1 versus F3 allowed good separation of two groups.

Keywords: Groundwater samples, Cluster Analysis, Principle component, Wadi Ranyah, Saudi Arabia

Introduction

In arid and semi-arid regions, groundwater is a significant part of the total water resources. One of the major problems encountered with groundwater chemistry evaluation is that there are large amounts of basic information regarding the groundwater quality in regional studies. The usefulness of water for particular purpose is determined by the water quality. The early study of the characterization of groundwater facies utilized graphical representations of the major compositions of groundwater. These classical classification techniques such as Stiff and Piper diagrams only consider selected major water constituents in determining the groundwater type (Hem, 1989). In recent years, with increasing number of chemical and physical variables of groundwater, a wide range of statistical methods are now applied for proper analysis and interpretation of data (Ashley & Lloyd, 1978; Usunoff & Guzman,1989; Suk & Lee, 1999 and Sanchez-Martos *et al*., 2001). Multivariate statistical analysis comprises a number of statistical methods or a set of algorithms that may be applied to several fields of empirical investigation. These methods of cluster analysis and principle component were used with remarkable success as a tool in the groundwater quality studies. These methods are also giving a better understanding of the physical and chemical properties of the groundwater system in space as well as in time (Helsel & Hirsch, 1992; Davis, 2002; Liu *et al*., 2003; Love *et al*., 2004 and Hussain *et al*., 2008).

Saudi Arabia is limited in agriculture and water resources. Farmers are heavily depending on groundwater. Wadi Ranyah is one of the most important alluvial aquifers in the western part of Saudi Arabia. Because of the rapid economic growth and lack of precipitation, the use of groundwater resource has increased dramatically, and the groundwater extraction has serious consequences such as 1) significant long time of low rainfall, 2) water-level decline, 3) increasing groundwater salinity, 4) contamination and 5) desertification (Subyani, 2004a). All these factors affect the quality of groundwater. The objective of this paper is to characterize the hydrochemical facies of groundwater system (major and minor components) present in the shallow alluvial aquifer situated in the western portion of Saudi Arabia, and use cluster and factor analysis.

Geology

Wadi Ranyah, the most important water resource in the western part of Saudi Arabia, is bounded by latitudes 20° 00′ and 20° 20′ N and longitudes 41° 40′ and 42° 00′ E. This wadi is a part of the escarpment of Hijaz Mountains of the Arabian Shield, which extends from north to south parallel to the Red Sea. This escarpment is one of the outstanding landscape features of Saudi Arabia. Wadi Ranyah originates from Baha Mountains and disappears in the desert in middle of Saudi Arabia towards the east (Fig. 1). Its drainage area is about 2500 km^2 and total length of the main channel is merely 80 km. The elevation of the Wadi decreases from 2500 to 1350 m above sea level from Baha Mountains in the west to the mouth of the wadi in the east.

In terms of the geological characteristics, several investigators have discussed various aspects concerning the geology of Wadi Ranyah (Brown & Jackson 1960; Greenwood 1975; Cater & Johnson 1986). Four principle units of Precambrian rocks (Ablah group) exist from the oldest to the youngest are showing in Fig. 2. These units are:

1. Qirshah Formation which is composed of metamorphic basaltic and subordinate andesitic, dacitic and rhyolitic pyroclastics,

2. Khutnah Formation includes siltstone and subordinate basaltic to andesitic flow rocks,

3. Thurat Formation consists mainly of metamorphosed volcanic wacke and sandstone,

4. In different parts of the area, these units are intruded by granodiorite and diorite plutons, and finally,

5. loose quaternary sediments fill the basin to a thickness of 5-10 m. These sediments consist of alternating layers of sands, gravel and clayey sand that were derived from host rocks, and provide the groundwater storage. The bedrock of the basin is highly weathered and fractured and also forms an ideal host for groundwater storage. These units are intensively faulted and folded and have a series of distinctive north-west and north-east trending faults.

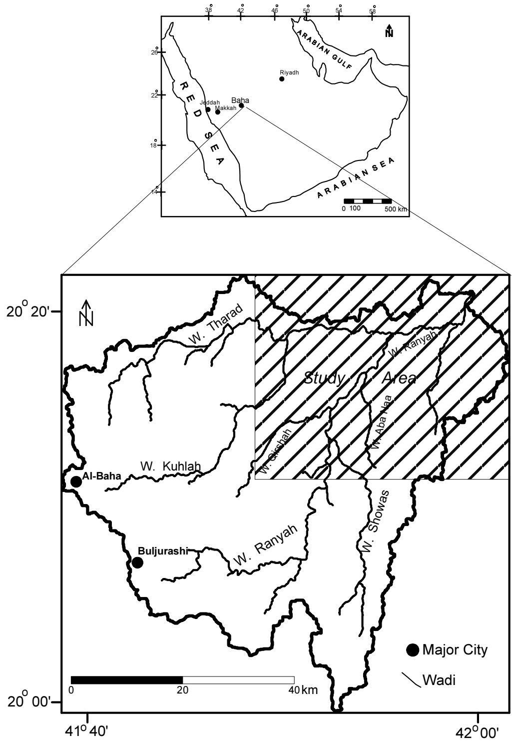

Fig. 1. Location map of the study area.

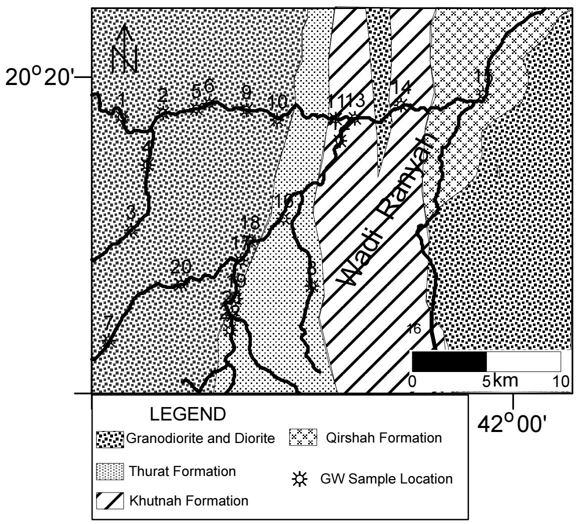

Fig. 2. Geological map of the study area and sampling points.

Hydrogeology

Rainfall in western Saudi Arabia can be described as scarce and unpredictable, but very extensive during local storms. The rate of evaporation is very high on the average of 400 mm/year. Wadi Ranyah basin receives a considerable amount of rainfall on the average of 450 mm/year (Ministry of Water and Electricity, 2007) (Fig. 3). Compared with other basins, it is mostly mountainous and is within a subtropical zone. Runoff occurs most of the year, especially, after rainfall events and flash floods occur in winter and spring seasons (Şen 1983; Subyani 2004b; and Alyamani, 1999).

Most of the wells in Wadi Ranyah are dug wells with an average diameter of 5 m and the total depth ranges from 9 to 22 m. These wells abstract groundwater from alluvial and fractured bedrock. The alluvial thickness ranges from 3 m in the upstream to 12 m in downstream. The depth to water table is also varying from 3 to 10 m with no systematic variation along the wadi course.

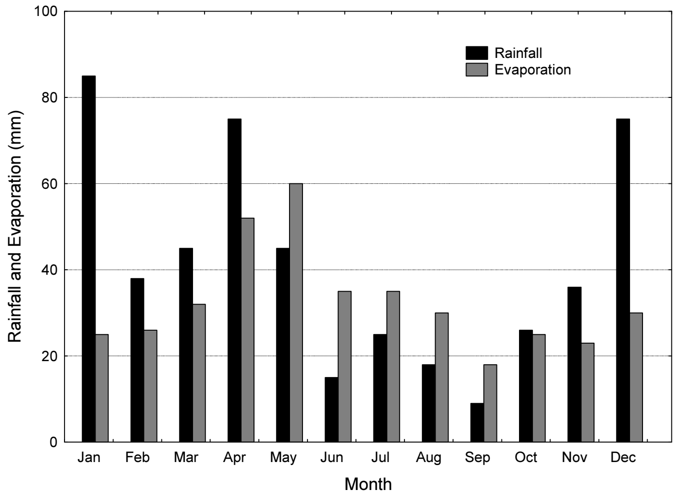

Fig. 3. Mean monthly rainfall and evaporation at Baha station (1980-2005).

Sampling and Methods

In this work, Twenty-two groundwater samples described herein were collected from shallow existing wells within the Quaternary and fractured aquifer during two weeks period in July 2007. Major and minor ion constituents analysis were carried out. Each water sample was analyzed to determine the concentration (milligram per liter) of major and minor ions (Ca^{+2}, Mg^{+}, Na^{+}, K^{+}, Cl^{-}, HCO_3^{-}, NO_3^{-}, SO_4^{-2}, F, PO_4, SiO_2, Ba, Cu, Mn, Pb, Zn, TDS and total hardness). Other descriptors pH, electrical conductivity (EC), and temperature were measured in the field. These water samples were analyzed by using Inductively Coupled Plasma-Mass Spectrometry (ICP-MS) in the laboratories of the Faculty of Earth Sciences, King Abdulaziz University, Jeddah, Saudi Arabia. Saturation indices for anhydrite (SI_{anh}), gypsum (SI_{gyp}), and halite (SI_{hal}) were also computed. Figure 2 shows the samples locations in the study area. The details of analytical data are given in Table 1. In addition, some descriptive statistics such as mean, standard deviation, coefficient of variation and skewness are also given. Table 2 shows the analytical data of minor ions with some descriptive statistics.

Durov diagram were drawn by plotting the major ions as percentages of milli-equivalents in two base triangles. The total cations and the total anions are set equal to 100% and the data points in the two triangles are projected onto a square grid that lies perpendicular to the third axis in each triangle. The main purpose of the Durov diagram is to show clustering of data points to indicate samples that have similar compositions (Hem, 1989). The water samples collected from study area were plotted on Durov diagram (Fig. 4). This figure showed that the water type in the study area is Calcium-Bicarbonate type, water is mainly in the upper reach where the recharge zone is located. Meteoric water infiltrates through the fracture rocks and alluvial deposits in some parts of the wadi. Durov diagram would be able to classify the water in the study area into one type. This is because the classification is just in terms of major ions, where minor and trace elements area excluded from Durov classification.

In addition, the saturation state of minerals in the water can be expressed by the saturation index (SI). When the $SI<1$, the minerals will be dissolved; and when the SI is >1, the minerals will be deposited (Freeze & Cherry, 1979). SI indices of halite, gypsum and anhydrite for the groundwater samples of Wadi Ranyah are shown in Table 1. All of the samples have negative halite, gypsum and anhydrite indices, which indicated that the groundwater is under-saturation state. Multivariate statistical techniques called cluster and factor analysis were applied to 21 variables as discussed in the following sections.

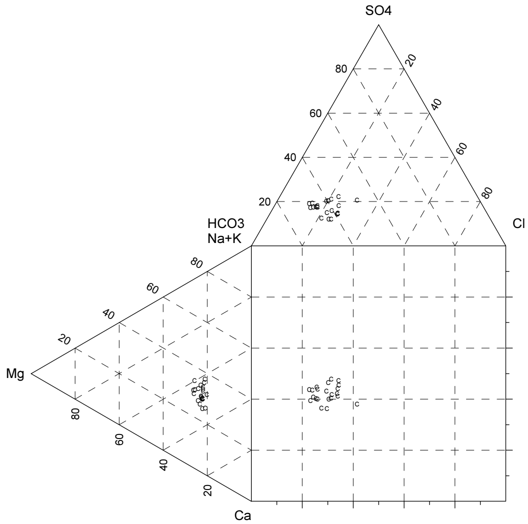

Fig. 4. Water types on Durov diagram.

Table 1. Major ions of groundwater samples of Wadi Ranyah (mg/l).

Sample ID	Ca	Mg	Na	K	Cl	HCo_3	No_3	SO_4	PH	EC µs/cm	C°	SI_{anh}	SI_{gyp}	Si_{hal}
1	47.3	13.4	27.3	1.6	49.98	135.1	6.64	44	7.25	454	23	-2.28	-2.1	-7.4
2	51.3	13.2	26.9	1.6	39.6	196	4.61	36	7.46	459	22	-2.33	-2.1	-7.5
3	38.6	13.7	27.8	1.5	40.64	158.2	4.31	29	7.38	416	24	-2.52	-2.3	-7.5
4	38	12.4	31.1	5.3	41.5	162.1	4.75	40	7.37	414	21	-2.39	-2.2	-7.4
5	41.5	12.2	28.7	1.5	41.6	160.2	4.83	30	7.37	425	25	-2.47	-2.3	-7.5
6	44.9	12.6	29.8	1.7	42	181	5.47	26	7.38	444	23	-2.51	-2.3	-7.4
7	37.7	12.6	30.4	1.6	41.91	162	3.36	31	7.35	421	24	-2.49	-2.3	-7.5
8	47.1	13.1	30.4	2	43.01	195.5	6.59	28	7.4	474	21	-2.47	-2.2	-7.4
9	52	12.6	28.1	1.7	38.14	207.6	1.86	29.8	7.37	484	25	-2.39	-2.2	-7.5
10	58	14.9	41.3	3.8	51.51	229.7	3.29	46.2	7.57	590	26	-2.19	-2.0	-7.2
11	44.1	13.3	36.6	2.9	30.48	205.4	1.35	41.6	7.49	467	24	-2.32	-2.1	-7.5
12	44	13.1	35.1	2.7	30.41	200.6	1.52	41	7.46	465	25	-2.32	-2.0	-7.5
13	47.5	14.7	45.6	4.6	41.72	202.8	1.88	56.4	7.48	538	23	-2.18	-1.9	-7.3
14	47	14.3	42.5	3.4	39	202.6	1.22	53	7.46	524	23	-2.21	-1.9	-7.3
15	51.4	14.9	39	3.3	37.6	204.4	5.1	52.4	7.37	534	22	-2.18	-1.9	-7.4
16	44.2	12.4	28.7	1.9	27.5	184.4	1.81	39.2	7.4	435	21	-2.34	-2.1	-7.6
17	44.3	12.2	29.1	1.8	26.5	184.8	2.96	38.2	7.4	433	24	-2.34	-2.1	-7.6
18	42	12.2	28.5	1.8	23.7	177.8	2.75	35.4	7.42	410	22	-2.4	-2.1	-7.7
19	45	13.7	28	1.7	23.4	190.7	5.39	36.9	7.41	436	25	-2.36	-2.1	-7.7
20	45.6	16.9	35.8	1.3	26.1	212.4	7.96	47.3	7.4	497	22	-2.27	-2.0	-7.6
21	46.5	16.7	37	1.2	25.5	227.9	8.31	49.2	7.5	520	21	-2.25	-2.0	-7.9
22	26.2	10.3	24.8	1.4	26.5	109.1	1.11	33.9	7.1	317	25	-2.57	-2.3	-7.7
Min	26.20	10.30	24.80	1.20	23.40	109.10	1.11	26.00	7.10	317.00	21.0	-2.57	-2.3	-7.7
Max	58.00	16.90	45.60	5.30	51.51	229.70	8.31	56.40	7.57	590.00	26.0	-2.18	-1.9	-7.2
Mean	44.74	13.43	32.39	2.29	35.83	185.92	3.96	39.30	7.40	461.68	23.2	-2.35	-2.1	-7.5
STD	6.33	1.52	5.77	1.13	8.54	29.04	2.20	8.76	0.09	57.85	1.6	0.12	0.1	0.14
Skew	-0.82	0.69	0.91	1.45	0.01	-0.93	0.42	0.34	-1.4	-0.03	-.01	-0.15	-0.2	0.00
CV	0.14	0.11	0.18	0.49	0.24	0.16	0.56	0.22	0.01	0.13	0.07	-0.05	-.06	-.02

Table 2. Minor ions of groundwater samples of Wadi Ranyah (mg/l).

Sample ID	F	PO_4	SiO_2	Ba	Cu	Mn	Pb	Zn
1	0.39	0.09	18.66	0.025	0. 8	0.1	0.37	2
2	0.37	0.09	18.36	0.024	0. 43	0.18	0.3	1.13
3	0.46	0.09	18.58	0.018	0. 5	0.1	0. 3	1.1
4	0.51	0.09	18.51	0.019	0.52	0. 1	0.3	1.8
5	0.49	0.09	18.28	0.019	0. 5	0.14	0.31	1.22
6	0.42	0.09	17.98	0.024	0. 52	0.11	0.34	1.28
7	0.57	0.09	17.51	0.022	0. 62	0.17	0.33	1.16
8	0.54	0.09	17.89	0.026	0. 52	0.36	0.35	1.24
9	0.34	0.12	18.25	0.022	0. 62	0.1	0.27	2.72
10	0.3	0.23	20.82	0.029	3.45	0.41	0.35	3.34
11	0.44	0.18	20.57	0.04	0. 67	0.61	0.31	1.08
12	0.42	0.23	20.76	0.035	0. 63	0.18	0.33	1.09
13	0.38	0.18	19.65	0.038	0. 7	0.46	0.39	1.29
14	0.4	0.19	20.44	0.037	0. 61	0.17	0.42	1.23
15	0.33	0.18	19.62	0.031	0. 42	0.1	0.29	1.31
16	0.38	0.14	19.43	0.036	0.48	0.11	0.26	1.08
17	0.39	0.14	20.42	0.035	0.46	0.1	0.28	1.12
18	0.37	0.19	19.9	0.036	0.39	0.45	0.27	1.08
19	0.36	0.15	20.72	0.040	0.46	0.11	0.3	1.07
20	0.45	0.19	24.33	0.038	0.43	0.21	0.25	1.57
21	0.46	0.23	24.46	0.029	0.73	0.1	0.27	1.31
22	0.3	0.1	13.59	0.021	0.02	0.95	0.36	0.0012
Min	0.30	0.09	13.59	0.02	0.02	0.10	0.25	0.00
Max	0.57	0.23	24.46	0.04	3.45	0.95	0.42	3.34
Mean	0.41	0.14	19.49	0.03	0.77	0.25	0.32	1.37
STD	0.07	0.05	2.25	0.01	1.02	0.22	0.05	0.65
Skew	0.49	0.35	0.08	-0.04	2.81	1.99	0.57	1.43

Cluster Analysis

Cluster analysis is the name given to an assortment of techniques designed to perform classification by assigning observation to group so each is more or less homogeneous and distinct from other groups (Hussain *et al*., 2008). So there are two types of cluster analysis: R and Q-modes. R-mode was performed on different water quality variables. Q-mode cluster analysis was performed on the water chemistry data to group the samples in terms of water quality (Davis, 2002; and Tabachnick & Fidell, 2006). So the hydrochemical results of all samples were statistically analyzed by using the software STATISTICA®. Generally, prior to cluster analysis data were normalized, the weight per group method was applied in Euclidean distance.

Factor Analysis

Factor analysis is a multivariate statistical technique that can be utilized to examine the underlying patterns or relationships for a large number of variables and summarize information in a smaller set of factors or components for prediction purposes (Davis, 2002). Principle component analysis (PCA) is the most frequently employed factor analytic approach. PCA defined as an orthogonal linear transformation that transforms the variables to a new coordinate system such that the greatest variance by any projection of the variables comes to lie on the first coordinate (called the first principal component), the second greatest variance on the second coordinate, and so on. PCA is theoretically the optimum transform for a given data in least square terms (Usunoff & Guzman,1989; Brown 1998; Ceron *et al.*, 1999 and Tabachnick & Fidell, 2006). To determine the number of components to extract, data obtained from laboratory and field analysis were used as variable inputs. Prior to the analysis, the data were standardized to produce a normal distribution of all variables (Jayakumar & Siraz, 1997 and Davis, 2002). The weights of the original variables in each factor are called loadings, each factor is associated with a particular variable. Communality is a measure of how well the variance of the variable is described by a particular set of factors (Grande *et al.*, 2003).

Results and Discussion

The analytical results of multivariate analysis were performed for the set of 22 samples and 21 variables. Figure 5 shows the R-mode cluster analysis dendogram of the 21 descriptors. The variables cluster into three major groups. From this dendogram one can find the relationship between different variables, the dendogram shows a high correlation between major ions (Ca^{2+}, Mg^{+}, Na^{+}, HCO_3^{-}, SO_4^{2-}), which indicated surface water recharge and water-rock interaction. Other group of total hardness, bicarbonate and salinity are highly associated with each other indicated recharge zone area. The third cluster shows the similarity between trace elements, nitrate, potassium and manganese as one group, which probably represents the effects of weathering of the rich feldspars and mica, in addition of agriculture fertilizers.

Figure 6 shows the clustering of the basins in Q-mode according the similarity. Two main groups can be verified in this figure. The first cluster shows a high similarity between the wells in the same geological formation (see Fig. 2). The second cluster shows a similarity between other wells which have been drilled in different geological formations.

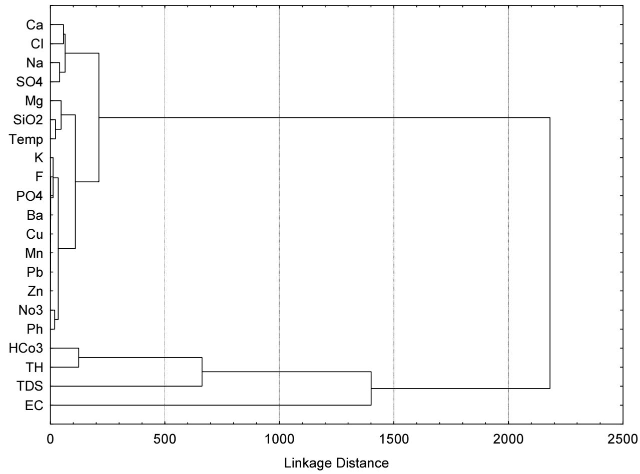

Fig. 5. Dendogram for 21 variables from cluster analysis in R-mode.

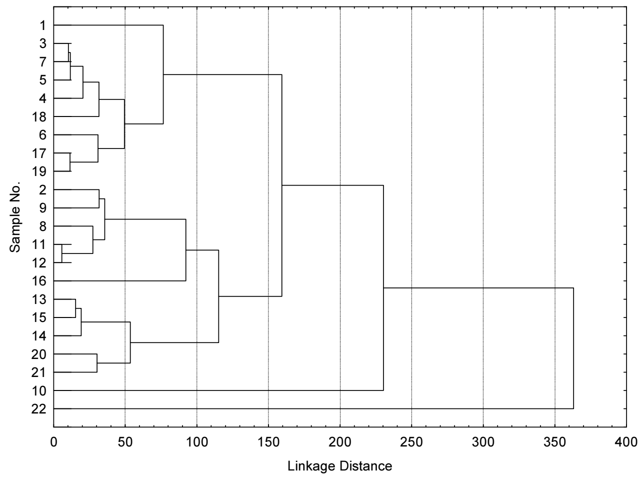

Fig. 6. Dendogram for 22 samples from cluster analysis in Q-mode.

Factor extraction was done by principle components. Table 3 shows the eigenvalues and cumulative variance for each factor. Figure 7 shows the scree plot with the successive eigenvalues in a simple line plot. The first three common factors were explaining 69.90% of the total variance. Table 4 shows the loading of each variable on each factor, and the percentage of the total variance accounted for in each factor in the rotated 3-factors model. The first rotated factor explaining 41.1% of the total variance, there are strong association between cations Ca^{2+}, Mg^{2+}, Na^{+}

and anions HCO_3^-, SO_4^{2-}, pH , TH and conductivity and trace elements as PO_4^{3-} and SiO_2. Phosphates (PO_4) primary come from shales and limestones and also from animal remains. From Table 2, phosphates concentration is exceeding the safe recommended level. Silica (SiO_2) is also abundant in the groundwater samples. The second rotated factor explaining 14.7% of the total variance, it represent the high loading of NO_3^- and Mn as the input of soil waters, but they are within the save natural concentration. The third rotated factor contributes only 12.6% of the total variance, the high loading of Chloride (Cl^-) and Zinc (Zn^{2+}) are only shown in this table. Cl^- represents flushing of evaporate minerals from sedimentary rocks, and Zn^{2+} is probably from the input of soil water.

Table 3. Eigenvalues and cumulative variances.

Factor	Eigenvalue	Cumulative Variances	Factor	Eigenvalue	Cumulative Variances
1	8.66	41.23	12	0.14	98.53
2	3.37	57.30	13	0.13	99.12
3	2.65	69.95	14	0.08	99.50
4	1.80	78.53	15	0.05	99.72
5	1.05	83.54	16	0.026	99.84
6	0.93	87.9	17	0.023	99.95
7	0.73	91.48	18	0.005	99.98
8	0.56	94.15	19	0.002	99.99
9	0.30	95.58	20	0.0007	99.99
10	0.26	96.82	21	0.00003	100.00
11	0.21	97.84			

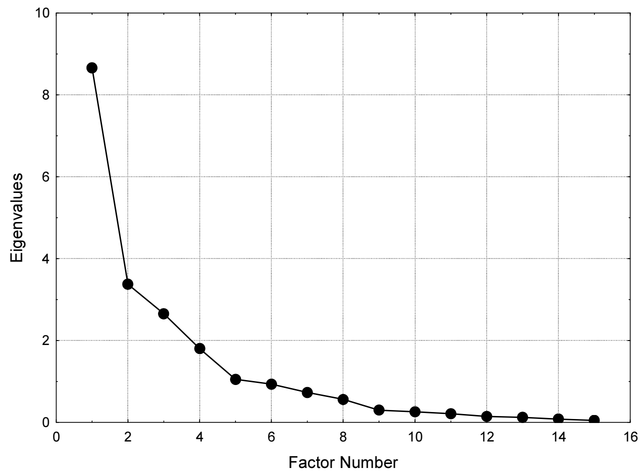

Fig. 7. Plot of eigenvalue.

Table 4. Varimax loading matrix.

Variable	**Factor 1**	**Factor 2**	**Factor 3**	**Communality**
Ca	**0.751479**	-0.180132	0.450758	0.800351
Mg	**0.828048**	-0.308740	0.022026	0.781469
Na	**0.811983**	0.317389	0.121465	0.774805
K	0.358944	0.414696	0.296860	0.388940
Cl	-0.049901	-0.048954	**0.929369**	0.868613
HCO_3	**0.899585**	-0.130192	0.026746	0.826919
NO_3	0.124722	**0.788584**	0.078014	0.643507
SO_4	**0.756520**	0.286630	-0.084767	0.661664
F	-0.203463	-0.558227	-0.041641	0.354749
PO_4	**0.828572**	0.323762	-0.259864	0.858883
SiO_2	**0.837086**	-0.315913	-0.275492	0.876410
Ba	0.681398	0.269467	-0.527916	0.815611
Cu	0.296157	0.439961	0.616996	0.661959
Mn	-0.215281	**0.738133**	-0.150160	0.613734
Pb	-0.079395	0.515037	0.420838	0.448671
Zn	0.257985	0.124564	**0.754408**	0.651204
Ph	**0.809535**	-0.089686	0.109127	0.675299
TH	**0.875462**	-0.174912	0.318095	0.898212
EC	**0.902936**	-0.023464	0.385451	0.964416
TDS	**0.834557**	-0.049714	0.243785	0.758389
Temp	-0.163492	0.514991	0.273536	0.366767
% of Variance	**41.1**	**14.7**	**12.6**	

Distribution of samples with respect of F1 and F2 is shown in Fig. 8. Factor 1 distinguishes samples in relation to the enrichment in cations (Ca^{2+}, Mg^{2+}, Na^{+}) and anions (HCO_3^{-}, SO_4^{2}). Sample 22, with the highest negative score is located in recharge zone with the lowest salinity among the samples and it comes from the most superficial well. Figure 9 shows plots of samples on F1 versus F3. The first factor appears in separating the calcium bicarbonate water (Group B), where Group A is less concentrated. Sample 10 shows the highest calcium bicarbonate with positive scores in F1 and F3 where sample 22 also shows negative scores. Varimax rotation of the three factors was performed, Table 5 shows the calculated scores for each sample.

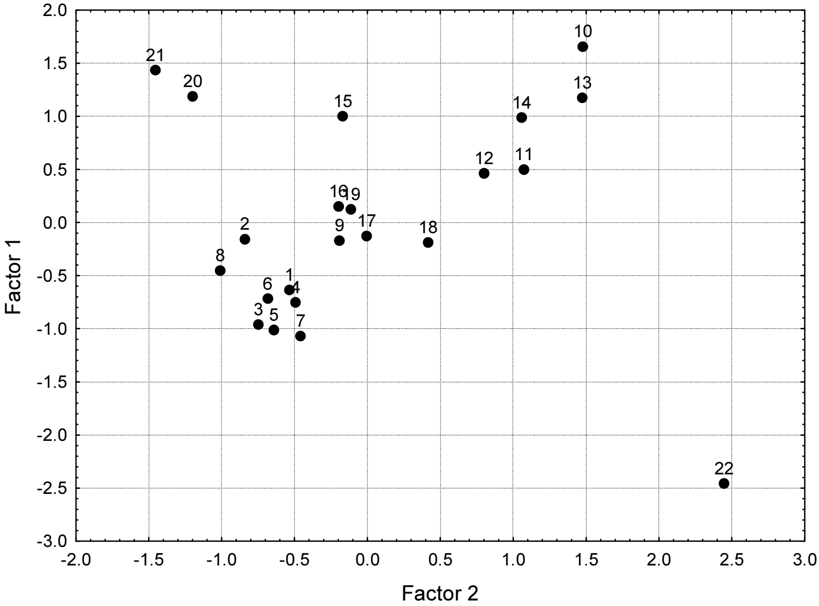

Fig. 8. Plot of Factor 1 versus Factor 2 scores.

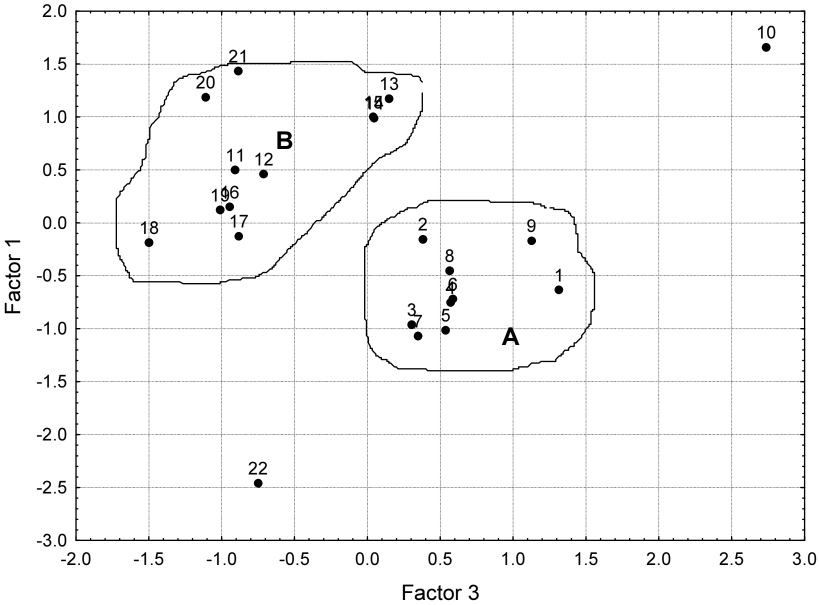

Fig. 9. Plot of Factor 1 versus Factor 3 scores.

Table 5. Variamax score matrix.

Sample	Factor 1	Factor 2	Factor 3
1	-0.63112	-0.53617	1.31500
2	-0.15480	-0.84050	0.38239
3	-0.96185	-0.74717	0.30555
4	-0.75075	-0.49239	0.57064
5	-1.01128	-0.64193	0.53713
6	-0.71790	-0.68506	0.58710
7	-1.06859	-0.45844	0.34657
8	-0.45175	-1.01020	0.56412
9	-0.16886	-0.19107	1.12731
10	1.65941	1.47722	2.73548
11	0.49924	1.07307	-0.90619
12	0.46254	0.79935	-0.71247
13	1.17609	1.47431	0.14800
14	0.98866	1.05766	0.04588
15	1.00121	-0.16936	0.03989
16	0.15090	-0.19978	-0.94502
17	-0.12484	-0.00668	-0.88397
18	-0.18467	0.41542	-1.49909
19	0.12405	-0.11410	-1.01142
20	1.18757	-1.19835	-1.11052
21	1.43450	-1.45325	-0.88566
22	-2.45775	2.44740	-0.75073

Conclusion

1. This study presented more detailed investigation of hydrochemical data on major and trace composition collected from shallow existing wells within the Quaternary and fractured aquifer of Wadi Ranyah in western Saudi Arabia.

2. Primary analysis of major ions shows that the groundwater is Calcium-bicarbonate water.

3. The applications of multivariate statistical techniques of cluster and factor analysis are considered to be useful tools for understanding and interpreting the data set.

4. Cluster analysis of R-mode shows two distinctive groups related to major ions high correlation, trace elements of water-rock interaction, agriculture and anthropogenic sources. Q-mode distinguishes between wells according to the similiraty of geological formations.

5. Principle component analysis shows that the first three factors are explaining 69.9% of the total variance.

6. Factor 1 represents evaporate minerals with positive scores.

7. Factor 2 revealed NO_3^- and Mn as the input of soil water.

8. Factor 3 shows flushing of evaporate minerals from sedimentary rocks.

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التحليل الإحصائي للمتغيرات المتعددة لنوعية المياه الجوفية في وادي رنية، المملكة العربية السعودية

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المستخلص. استخدمت التحليلات الإحصائية للمتغيرات المتعددة مثل تحليل المجموعات وتحليل المركبات لعدد ٢٢ عينة من المياه الجوفية جمعت من مواقع متاحة وممثلة تمثيلاً جيدًا لعدد من أفرع وادي رنية في الجزء الجنوبي الغربي من المملكة العربية السعودية. حللت العينات المائية لعدد ٢١ متغيرًا تشمل العناصر الرئيسة والنادرة. شملت الدراسة تعيين أولى لنوعية المياه في منطقة الدراسة من تحليل ديوروف حيث يغلب عليها سحنة كالسيوم-بيكربونات. بالإضافة إلى تحليل دلائل التشبع للمياه من كل من الجبس والهاليت والأنهيدريت حيث أظهرت النتائج أن المياه الجوفية غير مشبعة من هذه المعادن.

وباستخدام تحليل مجموعات العناصر وجدت مجموعتان بينهما علاقة قوية، مجموعة العناصر الرئيسة والتي تتأثر عادة بالتكوينات الجيولوجية المحيطة، والمجموعة الثانية والتي تحتوي على العناصر النادرة والملوثات والناتجة من النشاط الزراعي والبشري.

ومن تحليل المركبات وجد أن الثلاث مركبات الأولى تشرح حوالي ٧٠٪ من تباين القيم للعينات، حيث أوضحت المركبة الأولى

قوة العلاقة بين العناصر الرئيسة مثل الكالسيوم والمغنسيوم والصوديوم والبيكربونات والكبريتات والعسر الكلي بالإضافة إلى التوصيل الكهربي والسيليكات والفوسفات. أما المركبة الثانية فظهر تأثير النترات والمنجنيز وذلك من تاثير النشاط الزراعي. أما عنصر الكلور فظهر تأثيره مع المركبة الثالثة وذلك لقلة الملوحة في المياه الجوفية وقرب عهدها بالتغذية المطرية. كما أظهرت العلاقة بين المركبة الأولى والثانية أن العينات تقع في مجموعة واحدة تقريبًا مع فصل واضح للعينات الشاذة. أما العلاقة بين المركبة الأولى والثالثة فكونت مجموعتين من العينات.

الكلمات الدالة: عينات مياه جوفية، تحليل المجموعات، تحليل مركبات، وادي رنية، المملكة العربية السعودية