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***Research paper***

# Physicochemical Quality Assessment and Multivariate Statistical Analysis of Groundwater Quality in Basrah, Iraq

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**Abstract**

Groundwater is the very vital natural resource which must not be essentially utilized and sustained unless its quality is precisely evaluated. A total of 41 groundwater samples were collected from selected areas within Basrah province in 2014 to assess its suitability for irrigation uses. Physicochemical indices such as permeability index (PI 5.44 to 84.32 meq $L^{-1}$), percentage of sodium (Na% 8.87 to 51.03 meq $L^{-1}$) and sodium adsorption ratio (SAR 0.11 to 39.33 meq $L^{-1}$) indicate that the groundwater in the study area is suitable for irrigation except for few locations. The results show that the high values of total dissolved solids (TDS > 3000 mg $L^{-1}$) for some samples minimized their application for irrigation. Principal component and cluster analyses were usually used as a supporting tool for assistance arrange and interpret the chemical analysis. Three principal components explanation for most of the variability in the groundwater data were represented.

***Keywords***: *Assessment, Basrah , Groundwater , Irrigation water, Multivariate analysis..*

## 1. Introduction

Groundwater is a beneficial resource that is naturally available it does occur almost in every geological formation under the earth's surface. Groundwater acts as an important component as a decentralized provider of drinking water as well as satisfying the requirements for irrigation for millions of agricultural and urbanized families. For lots of communities which are rural, in the Zubair district, groundwater is a major source of water for irrigation and other applications.

The groundwater demand has increased for many years because of rapid urbanization, economic development, population growth, industrialization, as well as the agricultural expansion. Some specific attributes of groundwater along with the existence of dissolved minerals, in comparison with surface water, make groundwater is a selection that is recommended for many purposes (Rajankar et al. 2009). When the concentration of several organic and inorganic materials exceeds the tolerable range causes an effect that is undesirable for human health. Organized assessment of groundwater quality is essential for fulfilling the increasing water demand and important for the optimum application of obtainable groundwater on a maintained basis.

The quality of groundwater is, nevertheless, becoming decadent commonly because of several factors such as improper sewage management, overexploitation, and unsanitary circumstances existing in the rural higher application of fertilizers, insufficient water planning, and non-execution of planning measures. The quality together with the suitability of groundwater for different purposes such as industrial, domestic and agricultural uses depends upon the atmospheric precipitation, quality of recharge water, and interior surface water. There are some factors, which cause a variety of groundwater types; these are an ion-exchange process, groundwater residence time in the aquifers, and salt leaching (Sami 1992). The waste materials possibly are absorbed and transported to the groundwater, making the groundwater to be polluted, therefore the necessity for control and frequent monitoring of groundwater quality in these areas.

The oxidation-reduction reactions and rock-water interaction throughout the filtration of water in aquifers produce groundwater with different quality (Back 1966; Kumar et al. 2009; Aghazadeh and Mogaddam 2011).

Numerous researchers have been suggested various approaches to assess the data on water quality based on the aim, test types in addition to the sampling area. Al-Sadiy and Atiaa (2007) investigated the hydrological budget of the Dibdibba sandy aquifer for the duration from 1980 to 2000. They introduced a study for groundwater management resources. Al-Adhab (2011) used an investigation study to assess and discover the suitability of groundwater in Um-Qasr area for domestic and agricultural uses. He discovered that the origin of groundwater in that area was of a meteoric type, he also discovered that the groundwater is not suitable for drinking and agricultural purposes and if the groundwater used by farmers for irrigation, it is suitable for only date tree and some other crops. At-Temimi (2016) used geographical information system (GIS) to assess and identify the variation and the origin of groundwater Dibdibba aquifer south of Basrah. He used geostatistics interpolation technique in Arc GIS 10.2.2 to create the spatial distribution of studied parameters, he was found that the groundwater origin was the meteoric origin. Dawood and Ahmed (2016) evaluated the quality of groundwater Safwan, Zubair, and Um Qasir, south of Basrah Province for different purposes included industrial, construction and agricultural. The chemical results from their study indicated that the groundwater was unsuitable for industrial uses based on the standard classification and the groundwater was unacceptable for irrigation except for very salt-tolerant plants as well as excellent drainage, furthermore, based on Na% and SAR values of groundwater were classified as poor to very poor water type in the study area. Another study introduced by Abbas et al. (2017), for the same study area studied by Dawood and Ahmed (2016), evaluated the quality of groundwater and its suitability for drinking purpose by using the WQI. The results confirmed that the WQI values categorized groundwater from poor type to the unsuitable type for drinking purpose in the study area.

Zubair is the largest district in Basrah province. The different resources of irrigation water in Zubair city include groundwater available from western and southern aquifers. The quality of groundwater in Zubair district is based upon climate, the bedrock's geology, and the impacts of contamination from industrial and agricultural sources. Hence, the evaluation of groundwater is a must to identify its suitability for irrigation purpose in the study area.

In this paper, the percentage of sodium (Na%), permeability index (PI), residual sodium carbonate (RSC), and sodium adsorption ratio (SAR) that are recognized as the beneficial approaches to assess the groundwater quality (Srivastava and Sinha, 1994) were determined and assessed. This study aims at the investigation of the physicochemical parameters of groundwater quality of the study location to determine its suitability for irrigation purpose using the data acquired analysis and the standards for water quality. This research is used, Principal Components Analysis and the Cluster Analysis, as a complemental method to specify areas with degeneration in water quality and to find the potential sources of pollution in the study location.

## 2. Study area description

The study area lies in Zubair district, Basra Province. The study area is positioned between latitude 30°00' N and 30°30' N and longitude 47°35' E and 47°60' E. Fig. 1. displayed the map of wells location for the area under investigation.

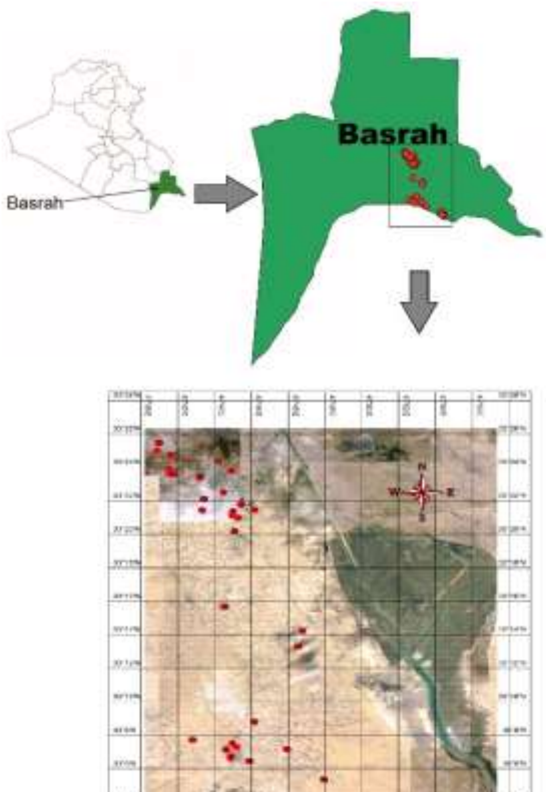


**Fig. 1:** Map showing the location of the study area

The location of the area is characterized by a hot desert climate where it obtains somewhat more precipitation than the interior locations because of its location close to the coastline. From June to August, Basrah probably one of the hottest cities in the world, having a temperature exceeding 50 °C in sometimes, whereas in winter, Basrah has mild weather with mean high temperatures near 20 °C, but in some winter nights, the minimum temperatures reach below 0 °C. The high humidity percentage in Basrah (sometimes going beyond 90%) is commonplace as a result of the closeness to the Persian Gulf marshy. The mean annual rainfall during the study was observed as 7.78 mm. Approximately 90 % of annual rainfall of Basrah province occurs during the months from November to April. In the study location, the minimum and maximum temperatures vary from 7.9 to 27.1 °C and from 17.6 to 45.6 °C, respectively, with a relative humidity varies from 16.6 to 57.1 % during the period from 2000 to 2013 [meteorological data 2013]. Recharge of water to the alluvial aquifers is caused by river beds flow, water bodies, precipitation, and return flow coming from irrigated areas.

The study area covers part of the southern section of the western desert and the southwestern part of the alluvial plain. The geological formations of the location of the study area consist of a mixture of rocks, anhydrite, dolomite, altered dolerites and black algal. The study area covered by different types of Quaternary sediments such as different rock fragments, sand, fine pebbles and rare clay. It consist of hard rock such as for instance hornblende-biotite gneiss, epidote-hornblende gneiss, and gray-brown to black sandy clay. The location of the area is a flat nature, which types the extension that is southern of vast Mesopotamian Plain and the extension that is eastern of Iraqi Southern Desert (Sissakian et al 2017). Fig. 2. displays the monthly minimum and maximum temperatures, distributions of rainfall, and relative humidity.

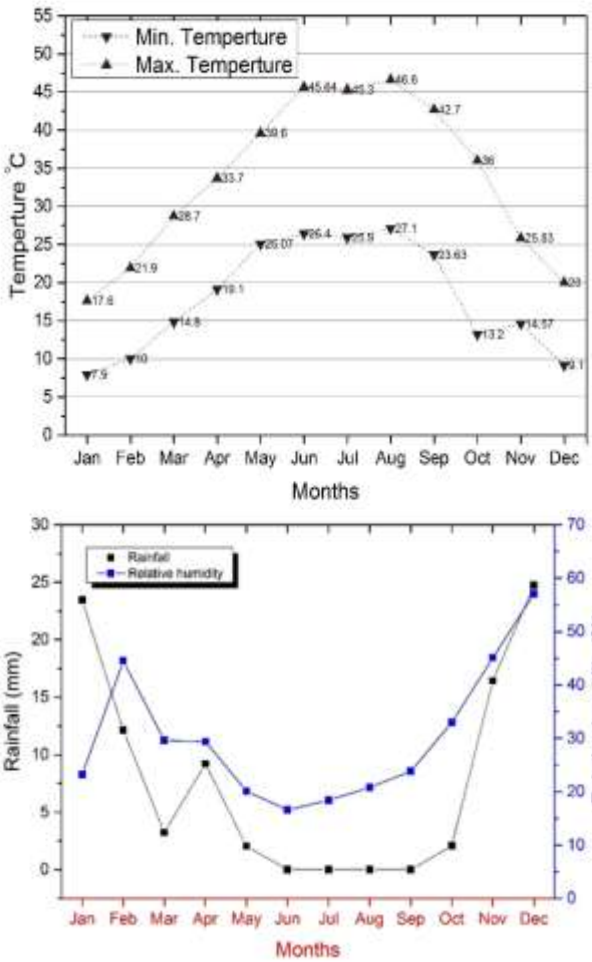


**Fig. 2:** The temperature distribution, relative humidity, and rainfall distributions in the study area.

## 3. Materials and Methods

A total of forty-one boreholes were sampled at different locations and collected for the study during 2014, as shown previously in Fig. 1. All the water samples from wells were collected in polyethylene bottles after it was rinsed many times with the water sample prior to fill it to the required water volume. Most the wells were getting used for irrigation water during the sampling period; that is why the purging of wells was continued for a few minutes.
From boreholes, the temperature, total dissolved solids (TDS), and electrical conductivity (EC) measurements were carried out on site using standard field devices, whereas the other tests of groundwater samples were measured in the laboratory of the Department of Environmental Protection and Improvement in the Southern Region. Analyses of the cations were conducted by Atomic Absorption Spectrophotometer ($Ca^{2+}$ and $Mg^{2+}$) and the Flame photometer ($Na^+$, $K^+$). The anions were analyzed were with ion chromatography ($Cl^-$, $SO_4^{2-}$, and $NO_3^-$). Simultaneously, the descriptive and multivariate statistics were carried out using the SPSS statistical package ver 20. The error from the ionic-balance is computed, using the relationship involving the total anions ($HCO_3^-$, $Cl^-$, $SO_4^{2-}$) and the total cations ($Ca^{2+}$, $Mg^{2+}$, $Na^+$, and $K^+$) for each sample of groundwater.
The comparison of groundwater quality depended on the maximum admissible value from the international standard of WHO (1984, 1998) for irrigation purpose and with the measured average values. The groundwater suitability for irrigation uses was examined by means of percent sodium, Na% (Todd 1980), calcium, RSC (Ragunath (1987), and the sodium adsorption ratio (SAR) (Richards 1954), the excess sum of bicarbonate and carbonate in water over the sum of magnesium.
In water, the $Na^+$ concentration plays a role that is a must in the categorization of water for irrigation because it is commonly used in the evaluating of water suitability for irrigation purposes (Wilcox 1955). This is because of the undeniable fact that the soil is affected by sodium reaction causing particles‘ clogging, therefore the permeability is reduced (Todd 1980). The concentration of $Na^+$ is commonly indicated in relation to percent sodium (Na%) and it is often expressed with regards to sodium percentage (Na%) and it is determined according to equation 1 (Todd 1980) :

$$\mathrm{Na\%} = \left(\frac{\mathrm{Na^+ + K^+}}{\mathrm{Ca^{2+} + Mg^{2+} + K^+ + Na^+}}\right) * 100 \quad (1)$$

Where all concentrations are evinced in meq/l.
The concentration of $Na^+$ is important in the investigation about the groundwater' suitability for irrigation given that the sodium high concentration causes advancement of an alkaline soil. Therefore, results of excessing $Na^+$ concentration in water causes unwanted ramifications of changing the soil properties.
Sodium adsorption ratio is refer to the degree to which usually irrigation water gets in soil by the reactions of cation ex-change (Manjusree et al. 2009). Those reactions making soil impervious and compact, due to the fact that $Na^+$ taking the place of the adsorbed $Ca^{2+}$ and $Mg^{2+}$ that is a risk since it triggers destruction to the soil structure. The SAR can be calculated using Equation 2 (Richards 1954):

$$\mathrm{SAR} = \frac{\mathrm{Na^+}}{\sqrt[2]{\frac{\mathrm{Ca^{2+} + Mg^{2+}}}{2}}} \quad (2)$$

Where all concentrations are evinced in meq/l.
Additionally, to Na% and SAR, the change among of surplus sum for bicarbonate and carbonate over the sum of magnesium and calcium in water is used to classify water for irrigation suitability. The quality of water is damaged when the levels of total carbonate exceed the total levels of calcium and magnesium. This damaged in water quality is due to the high excess of carbonate level generally regarded as“residual” mixes with magnesium and calcium to great a solid substance that settles out from water (Sundaray et al. 2009). This extra sum is indicated by ‘residual sodium carbonate’, and it can be expressed as RSC. The RSC can be calculated as proposed by Richard (1954):

$$\mathrm{RSC} = (\mathrm{HCO_3^-} + \mathrm{CO_3^{2-}}) - (\mathrm{Ca^{2+}} + \mathrm{Mg^{2+}}) \quad (3)$$

Where all concentrations of ions are evinced in meq/l.
Permeability Index (PI) is another useful tool to ascertain the water suitability for irrigation uses. The long-term usage of irrigated water affected by the contents of each of calcium, sodium, magnesium and the bicarbonate influences the permeability of the soil (Nagaraju et al. 2006). According to Doneen (1965), water can be classified based on the permeability Index, and PI can be calculated according to equation 4:

$$\mathrm{PI} = \frac{(\mathrm{Na^+} + \sqrt{\mathrm{HCO_3^-}}) * 100}{\mathrm{Na^+ + Ca^{2+} + Mg^{2+}}} \quad (4)$$

Where all concentrations of ions are evinced in meq/l.
The multivariate statistical methods, including Principal Component Analysis (PCA), Hierarchical Cluster analysis (HCA) and Factor analysis (FA) are designed to find and interpret the hidden and complex relationships among data attributes (Kowalkowski et al. 2006). The quantification of significant variables by explaining the patterns and groups of the properties that are inherently associated with the objects that are individual is the main idea of PCA. It is well-known that PCA is dependent on eigenvalue analysis of the covariance matrix or the correlation, no restrictions such as for instance the normality are required regarding the data (Meglin 1991). Therefore, for all original parameters attributes, the maximum explainable variance included by the determined Principal Component (PC) in an order that is descending (Marengo et al. 1995).
The FA utilized as a tool this is certainly valuable in the multivariate statistical method is used for extracting relationships or hidden information, which are not effortlessly observed amongst variables (Kowalkowski et al. 2006). FA produces a general relationship among the measured variables by exhibiting multivariate patterns to categorize the original-data. Furthermore, a matrix of original-data is diminished into another matrix called a product matrix contains loading and factor scores as well as the residual matrix. FA can easily determine various pollution factors moderately nevertheless the explanation of these factors with regards to actual sources that are controlling the processes, is extremely important (Bahar and Reza 2010).

## 4. Results and Discussion

The statistical summary of the physicochemical variables for the samples of groundwater in the study location is presented in Table 1.

**Table 1:** The statistical summary of physicochemical parameters (n=41)

| Parameters | Minimum | Maximum | Mean | Std.Dev. |
|---|---|---|---|---|
| pH | 6.6 | 8.7 | 7.34 | 0.373 |
| TDS | 1200.0 | 8990.0 | 4985.10 | 1759.475 |
| $Na^+$ | 12.2 | 3997.0 | 917.85 | 949.232 |
| $Ca^{2+}$ | 257.0 | 1002.0 | 592.72 | 179.791 |
| K | 0.0 | 267.2 | 57.87 | 69.112 |
| $Mg^{2+}$ | 4.0 | 316.4 | 150.75 | 70.256 |
| $SO_4^{2-}$ | 290.0 | 3408.0 | 1713.92 | 811.534 |
| $Cl^-$ | 249.6 | 4651.0 | 1880.86 | 1051.327 |
| $NO_3^-$ | 6.0 | 86.0 | 27.97 | 14.158 |
| $HCO_3^-$ | 61.0 | 3100.0 | 871.12 | 918.107 |
| EC | 1720.0 | 13890.0 | 7869.56 | 2674.375 |

Note: All values in mg/L excepting the pH and EC (µS/cm)

The pH of the collected samples ranges from 6.6 to 8.7 with an average of 7.34 pH units. The pH values suggest that the groundwater samples tend to be more of acid than alkaline. Usually, groundwaters revealed in the study area presented higher values of total dissolved solids, electrical conductivity, $Na^+$, $Ca^{2+}$, $Mg^{2+}$, $NO_3^-$, $K^+$, $Cl^-$, $HCO_3^-$, and $SO_4^{2-}$, when compared to those acquired in Dawood and Ahmed (2016), due to the fact that the groundwater might possibly be re-charged with evaporated water or sufficient irrigated (Gibrilla et al. 2010; Adomako et al. 2011). The quality of groundwater might additionally influence with the unsaturated zone activities earlier groundwater re-charge. The trend that observed is a normal phenomenon of discharge areas in which there is a long residence time for the groundwater.

The decline in productivity of the plants is due to the exorbitant level of dissolved ions in irrigated water. Therefore, the measure of electrical conductivity is an important key to determine the salinity hazard as it is a reflection of TDS level in the water. According to table 2, more than 95.1 % of the groundwater samples are unfit to use as irrigation water, whereas the rest of samples (2 samples) are useful for irrigation based on Davis (1966). Excessive salinity may possibly damage the growth of plant through restricting the uptake of water and nutrients by modification associated with the osmotic process (Todd 1980). The other effect of the excessive salinity is reactions that are chemically metabolic like those caused by toxic constituents (Todd 1980). Based on Ragunath (1987), the measure of EC is another indicator of the suitability or else of the groundwater using for agricultural purpose. Table 2, shows the classification of groundwater according to EC, it is noticed that about 4.9 % and 95.1 % of groundwater samples in the study location are doubtful and unsuitable for irrigation, respectively.

**Table 2:** Suitability of the groundwater samples for irrigation

| Quality parameter | Range | Classification | No of samples | % of samples | Sample number | % of samples | Reference |
|---|---|---|---|---|---|---|---|
| TDS (mg/L) | < 3000 | Useful | 2 | 4.9 | 5 , 29 | 4.9 | Davis (1966) |
| | > 3000 | Unfit | 39 | 95.1 | rest | 95.1 | |
| EC (µS/cm) | < 250 | Excellent | - | - | - | - | Ragunath (1987) |
| | 250-750 | Good | - | - | - | - | |
| | 750-2000 | Permissible | - | - | - | - | |
| | 2000-3000 | Doubtful | 2 | 4.9 | 23 , 29 | 4.9 | |
| | > 3000 | Unsuitable | 39 | 95.1 | rest | 95.1 | |
| Na (%) | < 20 | Excellent | 20 | 48.8 | rest | 48.8 | Ragunath (1987) |
| | 20-40 | Good | 11 | 26.8 | 1,3,5,7,12,15,17,20,24,26-27 | 26.8 | |
| | 40-60 | Permissible | 10 | 24.4 | 2,4,6,8-11,13-14,16 | 24.4 | |
| | 60-80 | Doubtful | - | - | - | - | |
| | > 80 | Unsuitable | - | - | - | - | |
| SAR | < 10 | Excellent | 27 | 65.9 | rest | 65.9 | Richards (1954) |
| | 10-18 | Good | 8 | 19.5 | 1,3,7,11,12,14,16,17 | 19.5 | |
| | 18-26 | Doubtful | 3 | 7.3 | 2,9,13 | 7.3 | |
| | > 26 | Unsuitable | 3 | 7.3 | 6,8,10 | 7.3 | |
| RSC | < 1.25 | None | 40 | 97.6 | rest | 97.6 | Ragunath (1987) |
| | 1.25-2.5 | Slight- moderate | 1 | 2.4 | 16 | 2.4 | |
| | > 2.5 | Severe | - | - | - | - | |
| PI | 75 % or more Max. permeability | Classes I and II (Good) | 41 | 100 | all | 100 | Doneen (1965) |
| | 25 % Max. permeability | Class III (Unsuitable) | - | - | - | - | |

Sodium concentration plays a part that is essential to evaluate the groundwater quality for irrigation because, at high sodium level in water that uses for irrigation works, the clay particles of soils absorbed the sodium ions and displacing calcium and magnesium ions. The results of Table 2 revealed that 48.8 % and 26.8 % of the groundwater samples in the area under investigation be in the excellent to good class, while 24.4 % of the groundwater samples be under admissible class for using water for irrigation as outlined by Ragunath (1987). Hence, high values of Na % (Table 2), will likely not offer the utilization of this water for irrigation.

The results of the SAR index (as shown in Table 2) for the groundwater samples presents that 65.9 % and 19.5 % of the groundwater samples belong to the class of excellent to good, respectively. The rest of the groundwater samples, nonetheless, exhibited only 7.3 % in the doubtful class with 3 samples and 7.3 % falling under unsuitable class with also three samples. The SAR data reveal that the excellent class of water for irrigation purposes offer that no alkali hazard is expected to affect crops from the irrigated water.

The RSC is another factor to check the groundwater suitability in the study location for agricultural purpose. This is assessed by making use of the RSC, Ragunath (1987). As shown in Table 2, the categorization of groundwater for irrigation purposes is done in accordance with the US Salinity Laboratory ( Richards 1954) and it is noticed that 97.6 % of groundwater samples was safe for irrigation because the RSC values of it are less than 1.25 meq/l. While just one sample was marginal quality due to that fact that the RSC values ranged between 1.25 to 2.5 meq/l (Nagaraju et al. 2006) Additionally, the negative RSC values for 40 samples (97.6 % of total samples ) at most sampling locations suggests that there's no full precipitation of magnesium and calcium ions (Tiwari and Manzoor 1988). Furthermore, the Na % and SAR, the excess amount of both bicarbonate and carbonate over the sum of magnesium and calcium in water, always impact the relevance of water to use it in irrigation. Finally, according to Table 2, the usability of the groundwater samples for irrigation purposes in the study location depends on the determined RSC values (Table 2) suggested that the groundwater tend to be safe from bicarbonate hazard.

In accordance with the criterion, water could be categorized into three Classes. The classes I and II are classified water to be of good quality and suitable for irrigation, with 75% or more maximum permeability. Whereas, the class III regards the water is unsuitable for irrigation, with 25% maximum permeability. All samples of the groundwater in the study location (see Fig. 3 and Table 2) falls in Classes I and II; therefore, considering Doneen’s chart, the groundwater in the study area tend to be suitable for irrigation.

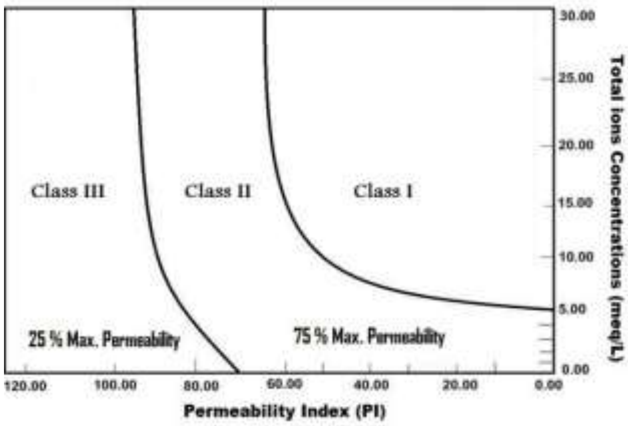


**Fig. 3.** Doneen's Chart (1964) for PI classifications

In this study, the principal components analysis on the mixed data sets presented three factors with an eigenvalue greater than unity that explained about 72.1 % of the variance or information contained in the original dataset (Figure 4). Therefore, the three factors can help to explain the processes that are hydrochemical without losing any considerable characteristics within the data structure. Based on the absolute loadings, Liu and Kuo (2003) classified values between 0.40 and 0.50 as "weak", values between 0.50 to 0.75 as "moderate", and values more than 0.75 as "strong". According to this classification, the absolute loadings of equal or greater than 0.4 will be displayed in bold fonts as shown in Table 3.

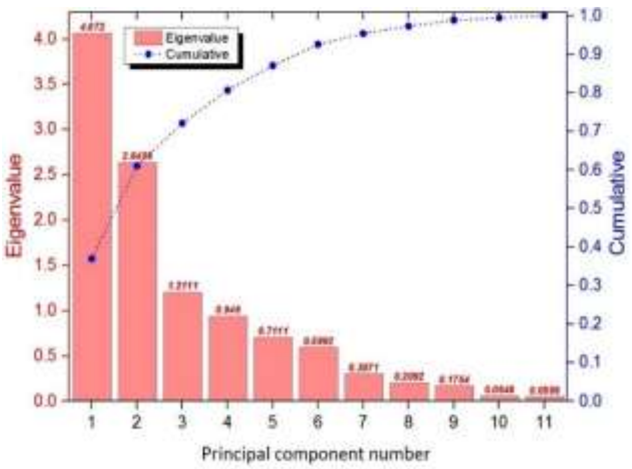


**Fig. 4.** Score and cumulative plots for all principal component numbers generated from the study area data.

The first factor, principal component 1 (PC1), has an eigenvalue of 4.072 and accounts for 37.0 % of the total variance. This factor is actually weakly loaded with each of TDS and $SO_4$ (Table 3). The loading of this factor may imply the high salinity because of the seawater impact increased by the flushing that came from tidal (Edet and Worden 2009; Edet et al. 2012). This factor also provides a sense of the parameters controlling the total dissolved solids as well as the electrical conductivity.

The second principal component (PC2) explains 24.1 % of the total variance and is dominated by three main parameters which are Na, Cl, and $HCO_3$. This factor has an eigenvalue of 2.6456. The $HCO_3$ may come from the carbonate minerals dissolution or from degradation of bacteria as documented (Bahar and Reza 2010).

The third factor, principal component 3 (PC3), is weakly loaded with the pH and K. This factor explains 11.0 % of the total variance with an eigenvalue of 1.2111.

**Table 3**: Eigenanalysis of the Correlation Matrix with the Eigenvectors for the groundwater parameters

| Variable | Factors | | |
|---|---|---|---|
| | PC1 | PC2 | PC3 |
| pH | 0.263 | -0.154 | **0.405** |
| TDS | **0.473** | 0.048 | 0.078 |
| EC | 0.394 | 0.29 | 0.054 |
| $Na^+$ | -0.09 | **0.573** | -0.011 |
| $Mg^{2+}$ | 0.226 | 0.17 | 0.348 |
| $Ca^{2+}$ | 0.28 | -0.012 | -0.66 |
| $K^+$ | 0.195 | -0.084 | **-0.482** |
| $Cl^-$ | 0.209 | **0.485** | -0.123 |
| $NO_3^-$ | 0.332 | 0.081 | 0.147 |
| $SO_4^{2-}$ | **0.417** | -0.198 | 0.019 |
| $HCO_3^-$ | -0.221 | **0.493** | -0.014 |
| Eigenvalue | 4.072 | 2.6456 | 1.2111 |
| % Total variance | 37 | 24.1 | 11 |
| Cumulative Eigenvalue | 4.072 | 6.7176 | 7.9287 |
| % Cumulative total variance | 37 | 61.1 | 72.1 |

The Hierarchical Cluster Analysis (HCA) is applied for identifying the relationship amongst the assorted sampling points (wells) using a measure of similarity by Euclidian distance as express as Ward's method. Figure 5, shows the dendrogram of the producing HCA of the field data wherein three main groups from the groundwater samples (field data) were visually preferred. The first group (cluster I) comprises wells 1, 3, 7, 11, 15, 16, 2, 14, 9, 12, 13, 17, 31, 41, 33, 21, 26, 39, 36, 38, 24, 6, 8, and 10. This group is described as contaminated areas and their contamination source mainly the geological structure of the soil. The second group (cluster II) comprises wells 18, 19, 22, 20, 34, and 40. This group shows less than contamination from the first group, whereas, the third group (cluster III) comprises wells 4, 5, 25, 28, 35, 30, 27, 32, 23, 37, and 29. This group shows that groundwater in these locations may be progressively being suffering from anthropogenic activities.

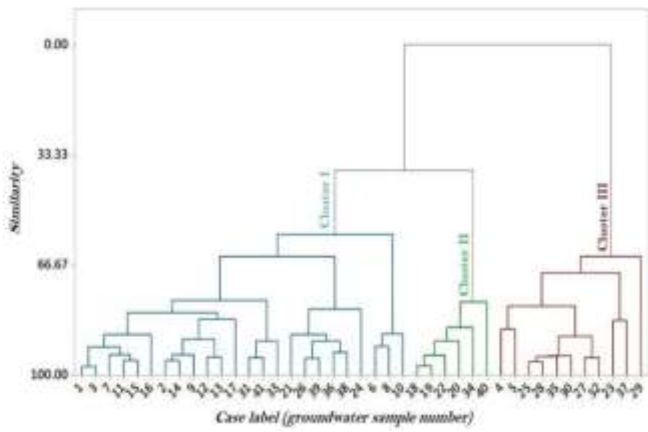


**Fig. 5.** Dendrogram representing the relationship between samples.

## 5. Conclusions

The qualities of groundwater in Basrah district, south of Iraq, has been assessed for its viability for irrigation needs. The amounts of most parameters were significantly different for the study location due mainly to some factors. The total dissolved solids, percent sodium, sodium adsorption ratio, residual carbonate, and permeability index data suggest the groundwater tend to be appropriate for irrigation purposes, although the data for the electrical conductivity indicates its unsuitability for the same purpose. The HCA and PCA determined three components whereas the score plots delineated polluted and prospective deterioration locations. The principal components analysis of the mixed data sets explained about 72.1 % of the variance included in the original data-sets.

To evaluate the groundwater for irrigation uses, Na%, SAR, RSC, TDS, and PI were included. The results show that most of the groundwater samples were suitable for irrigation with some places in the study locations that belong to the doubtful and unsuitable class. An overall assessment determined by some water quality parameters signifies that fairly, the water of the study location is suitable for irrigation purposes.

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