Geochemical Assessment of Quaternary aquifer in El Fayoum Depression, Western Desert, Egypt

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ABSTRACT

Groundwater in El Fayoum governorate has a particular importance where it is the source for fresh water used for drinking, agricultural, domestic, and industrial purposes. Thirty-eight groundwater wells were available during summer 2017 and were analysis for physiochemical characteristics. These data has been used to evaluate groundwater for drinking and irrigation purposes by comparing physiochemical parameters with world health organization (WHO) standards. Results show that **60.5%** of Na^+ concentrations in groundwater samples are above this limit. **86.84%** of K^+ concentrations in groundwater samples are above this limit. The desirable limit for Ca^{2+} for drinking water is specified as **75** mg/l (WHO 2011). About **84.2**% of groundwater samples in study area exceed the permissible limit according to WHO standards. Most of the Mg^{2+} concentrations **84.2%** are above the desirable limit of **50** mg/l. About **97.36%** of total wells over the permissible limit of HCO_3^- which is**120** mg/l. About 14 wells **36.84%** are within the desirable limit of **250** mg/l. The desirable limit of Cl^- for drinking water is specified as **250** mg/l according to WHO and **30** wells **78.94%** are above this limit.Groundwater wells were classified according TDS as about 89.47 % of tested samples have contents ranging from >1000 mg/l.

Key words: Physicochemical parameters, Groundwater, Quaternary aquifer, El Fayoum Depression, Egypt

الملخص

المياه الجوفية في منطقة الفيوم لها أهمية خاصة حيث أنها مصدر المياه العذبة المستخدمة للشرب والأغراض الزراعية والمنزلية والصناعية. تم تحليل 38 عينة مياه جوفية خلال صيف 2017 وخضعت لتحليل الخصائص الفيزيائية والكيميائية. تم استخدام هذه البيانات لتقييم المياه الجوفية لأغراض الشرب والري من خلال مقارنة المعلمات الفيزيوكيميائية مع معايير منظمة الصحة العالمي (WHO). أظهرت النتائج أن 60.5٪ من تركيز Na^+ في عينات المياه الجوفية أعلى من هذا الحد. 86.84٪ من تركيزات K^+ في عينات المياه الجوفية أعلى من هذا الحد. تم تحديد الحد المرغوب فيه لـ Ca^{2+} لمياه الشرب على أنه 75 مجم / لتر (منظمة الصحة العالمية 2011). وجد أن 84.2٪ من عينات المياه الجوفية في منطقة الدراسة تتجاوز الحد المسموح به وفقًا لمعايير منظمة الصحة العالمية. معظم تركيزات Mg^{2+} وهي تمثل 84.2 % أعلى من الحد المرغوب فيه وهو 50 مجم / لتر. حوالي 97.36٪ من إجمالي الآبار فوق الحد المسموح به من HCO_3^- وهو 120 مجم / لتر. يوجد حوالي 14 بئراً حوالي 36.84٪ ضمن الحد المرغوب فيه وهو 250 مجم / لتر. تم تحديد الحد المرغوب

من Cl^- لمياه الشرب على أنه 250 ميكرولتر / لتر وفقًا لمنظمة الصحة العالمية و 30 بئراً تمثل 78.94٪ أعلى من هذا الحد. تم تصنيف آبار المياه الجوفية وفقًا لمجموع المواد الصلبة الذائبة حيث أن حوالي 65.78٪ من الآبار تحتوي على نسبة أقل من 3000 مجم / لتر وبالتالي فإن المياه الجوفية مناسبة للري

الكلمات الدالة : الخصائص الفيزيائية والكيميائية ، المياه الجوفية ، الخزان الجوفي الرباعي ، منخفض الفيوم ، مصر

INTRODUCTION

Groundwater in El Fayoum area has a particular importance where it is the source for fresh water used for agricultural, domestic, and industrial purposes. (Mohamed A. Dawoud et al., 2005) Groundwater resources of El Fayoum, Egypt subject to a very serious problem which is contaminated from agricultural and urbanization activities. Groundwater is exposed to contamination by many pollutants due to agricultural activities and extensive use of agrochemical fertilizers which lead to reduce the groundwater quality (Ahmed, 2012).

The parameters of water quality i.e. pH, EC, TDS, Na^+, Ca^{2+}, Mg^{2+}, k^+, SO_4^{2-}, HCO_3^- and Cl^- should be in permissible limits according to drinking water standards of WHO (2011) and. If these parameters cross the permissible limit of concentration, it may causes serious health hazards and such water is known as contaminated water. The objective of this study is to evaluate groundwater quality where upon can determine its suitability for different uses through comparing Physiochemical parameters which are TDS, Na^+, Ca^{2+}, Mg^{2+}, k^+, SO_4^{2-}, $HCO_3^-$and Cl^- with WHO standards.

2. Study area

The study area is geographically located between latitudes 29° 00\` and 29° 30\` N and longitudes 30° 20\` and 31°10\` E, with an area of about 1200 km^2 (Fig.1). The study area involves six districts (Tamia, Sinnoris, Ibshawai, Fayoum, Yousef El Sadik, and Itsa).El-Fayoum is an oasis, surrounded by desert from all directions except form the south-east direction where it is connected to the Nile Valley by a Canal called Bahr Youssef.

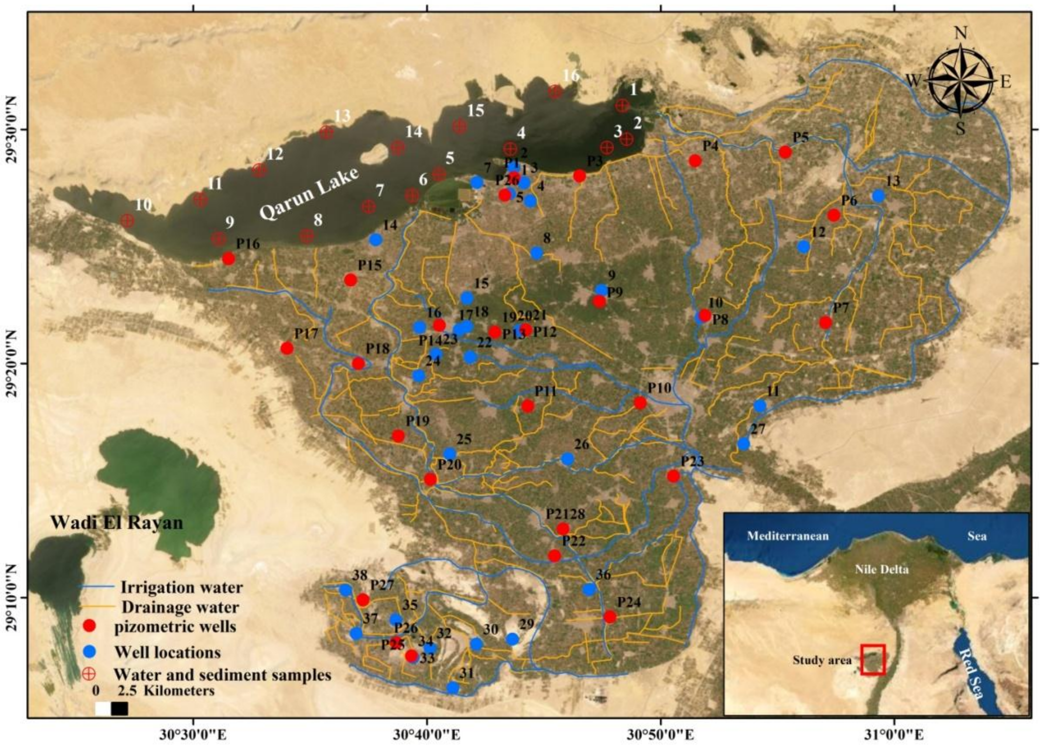


Fig.1. Location of the study area and measuring points.

3. Geological and hydrogeological settings

El-Fayoum basin was initially formed during the Jurassic Period, probably by wind erosion in the desert, and its current shape created from tectonic subsidence that terminated in the late Eocene Epoch. The basin then subsided relative to the Nile, allowing the river to break through in flood and deposit fertile alluvial sediments. Rock units that exposed in El-Fayoum region range from Eocene to Quaternary ages as shown in (Fig.2). In the study area, the subsurface stratigraphic column is capped by the Pleistocene deposits that are widely distributed over the entire area of El-Fayoum area. These deposits are mainly of fluvio-lacustrine origin, and composed of varied grain sizes of sand and gravel intercalated with silt and clay. The thickness of the Quaternary deposits varies from place to place. It reaches to about 50 m at the center of the depression and varies according to the configuration of the underlying limestone rocks. Structurally, El-Fayoum depression has been affected by several distortion lines (faults, breaks, etc.) in addition to some folds. The distortion lines are particularly dominant at the edges of the depression with NS and NW-SE striking directions (Ahmed, 2012).

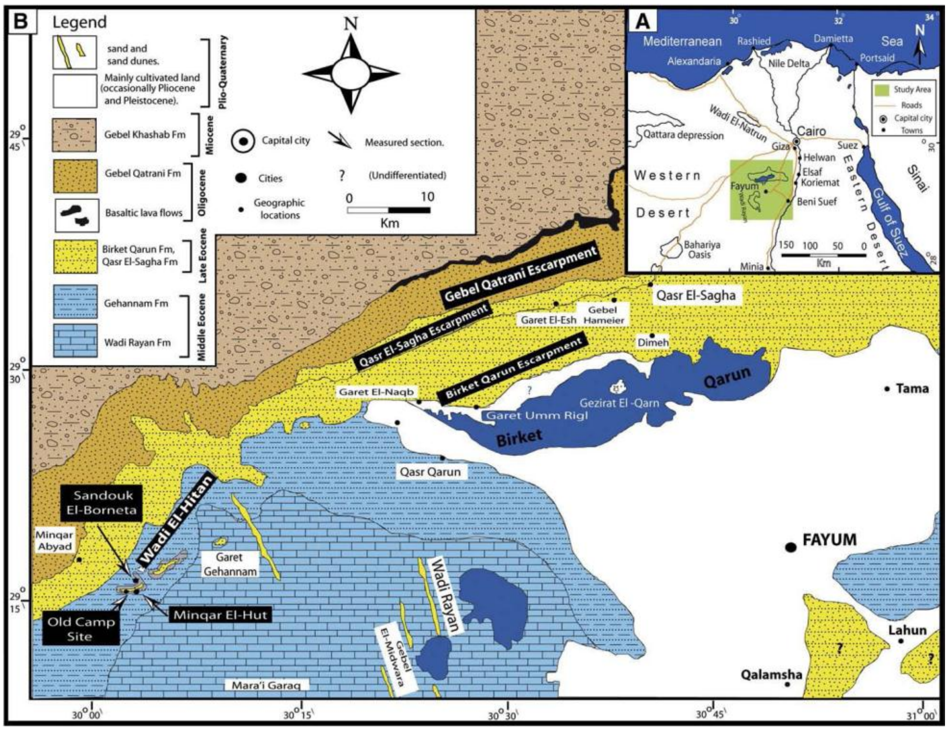


Fig.2.Geological map of El-Fayoum and its adjacent area (Ahmed, 2012).

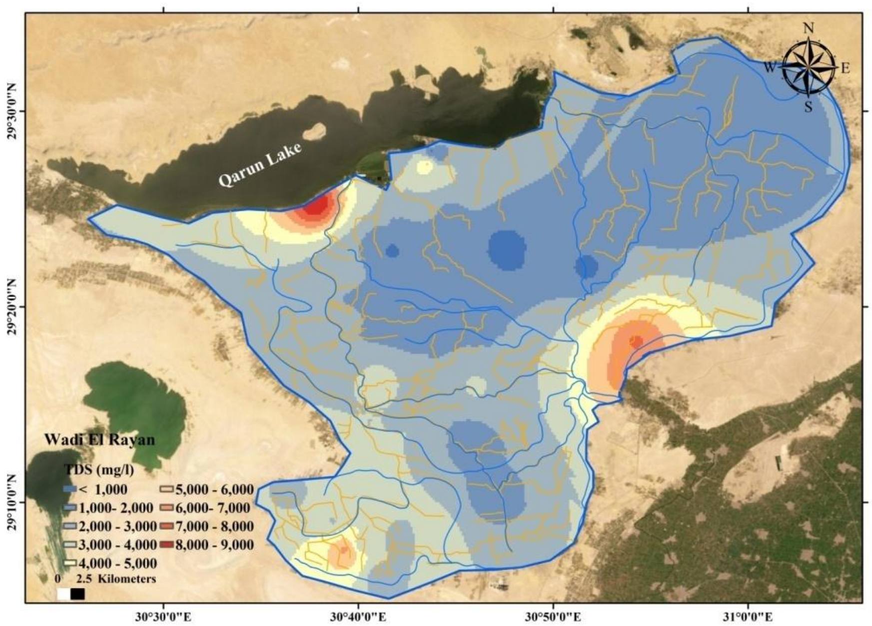
4. Methodology

Groundwater samples were collected from 38 shallow wells at depths less than 60 m, representing the Quaternary aquifer, during one season; September 2017. The samples were collected in pre-marked 500 ml polyethylene bottles. Prior to filling of the bottles, they were rinsed by deionized water and then by water to be sampled. Immediately after filling the bottles, they were closed and caps were tightened securely to prevent interaction of the samples with the atmosphere. The samples were kept in cooler tanks and transported to the laboratory and kept at temperatures below 4 $^{\circ}$C for analyzing processes Physiochemical parameters; pH, EC, TDS, Na^{+}, Ca^{2+}, Mg^{2+}, k^{+}, SO_4^{2-}, HCO_3^{-} and $Cl^{-}$of the collected samples were measured using a measured multi-parameter professional plus handheld tool and inductively coupled plasma optical emission spectrometry (ICP-MS).The dissolved water samples were filtered for analysis for Na^{+} and K^{+} by flame spectrometry, Ca^{2+} and Mg^{2+} by EDTA titration, HCO_3^{-} and CO_3^{2-} by acid titration, Cl^{-} by $AgNO_3$ titration, and SO_4^{2-} by $BaCl_2$ titration, Total dissolved solid (TDS), were measured gravimetry. The basic physical and chemical properties of the water samples, including pH were measured by a portable multi-parameter water quality analyzer (HQ40d, Hach Corporation, USA). The analytical precision of the measurement of ions was determined by calculating the ion balance error, which was within 5%.

5. Results and discussion

5.1 Total dissolved salts (TDS)

The TDS values of the groundwater of the basin range from 614.3 mg/l in (W9) to 8950 mg/l in (W14) with an average of 2761.81 mg/l. according to WHO 2011 (Table1). Salinity content shows increase from south to north direction. About 2.63 % of tested samples have salinity content ranging from 500-750 mg/l. About 7.89 % of tested samples have contents ranging from 750-1000 mg/l. In addition, 89.47 % of tested samples have contents ranging from >1000 mg/l (Fig.3).



(Fig.3): Salinity distribution contour map of the production wells.

Table 1: Classification of groundwater to evaluate its suitability for drinking

Parameters	Min	Max	Average	WHO (2011)
PH	**6.4**	**8.90**	**7.53**	**6.5–8.5**
EC	**612**	**13358.00**	**4197.19**	**1500**
TDS	**614.3**	**8950.00**	**2761.81**	**500**

Ca^{2+}	**46.4**	**602.40**	**200.67**	**75**
Mg^{2+}	**24**	**279.8**	**94.09**	**50**
Na^{+}	**110**	**2094.80**	**566.11**	**200**
K^{+}	**6**	**180.00**	**35.23**	**12**
Cl^{-}	**85**	**1992.00**	**665.15**	**250**
HCO_3^{-}	**72.00**	**787.00**	**393.64**	**120**
SO_4^{2-}	**51.6**	**3370.20**	**751.13**	**250**

5.2 Hydrogen ion concentration (PH)

The pH of the groundwater in the study area is within the recommended tolerance interval (pH= 6.5 – 8.5) and is ranging from 6.4 in (W18) to 8.90 in (W17) with an average of 7.53 (Table1), according to WHO 2011. Hence, the groundwater is suitable for drinking purpose. The higher value recorded in the north western part of the area .This is due to the liquid waste discharged from the surrounding factories

5.3 Electric conductivity (EC)

The EC values of the groundwater of the basin range from 612 mg/l in (W9) to 13358 mg/l in (W14) with an average of 4197.19 mg/l. (Table1) according to WHO 2011. Electrical conductivity content shows increase from south to north direction.

5.4 Spatial distribution of major cations

5.4.1 Distribution of sodium concentration:

Sodium is an abundant element having a value ranges from 110 mg/l in (W9) to 2094.80 mg/l in (W14) with an average of 566.11mg/l. The majority of groundwater samples have Sodium contents ranging from 100 to 200 mg/l with percentage of 39.47% (Fig.4).

5.4.2 Distribution of potassium concentration

Potassium is an abundant element having a value ranges from 6 mg/l in (w9) to 180 mg/l in (w14) with an average of 35.23 mg/l (Table1) according to WHO 2011. The maximum concentration observed in the western, south and northwestern part of the area (Fig 4) .The majority of groundwater samples in the study area have potassium content ranging from 6 mg/l to 10 mg/l with percentage of 5.26 %.

5.4.3 Distribution of magnesium concentration

Magnesium is an abundant element having a value ranges from 24 mg/l in (w9) to 279.8 mg/l in (w14) with an average of 94.09 mg/l (Table1) according to WHO 2011. The majority of groundwater samples in study area have magnesium content ranging from (40 – 279.8mg/l) recorded 94.73% of groundwater in the study area. Magnesium content shows increase from south to north direction (Fig 4).

5.4.4 Distribution of calcium concentration

Calcium is an abundant element having a value ranges from 46.4 mg/l in (W10) to 602.4 mg/l in (W14) with an average of 200.67 mg/l (Table1) according to WHO 2011. The maximum concentration observed in the western, south and northwestern part of the area (Fig.4). The majority of groundwater samples have calcium contents ranging from 100 to 602.4 mg/l with percentage of 71.05 %. Calcium content shows increase from south to north direction (Fig.4).

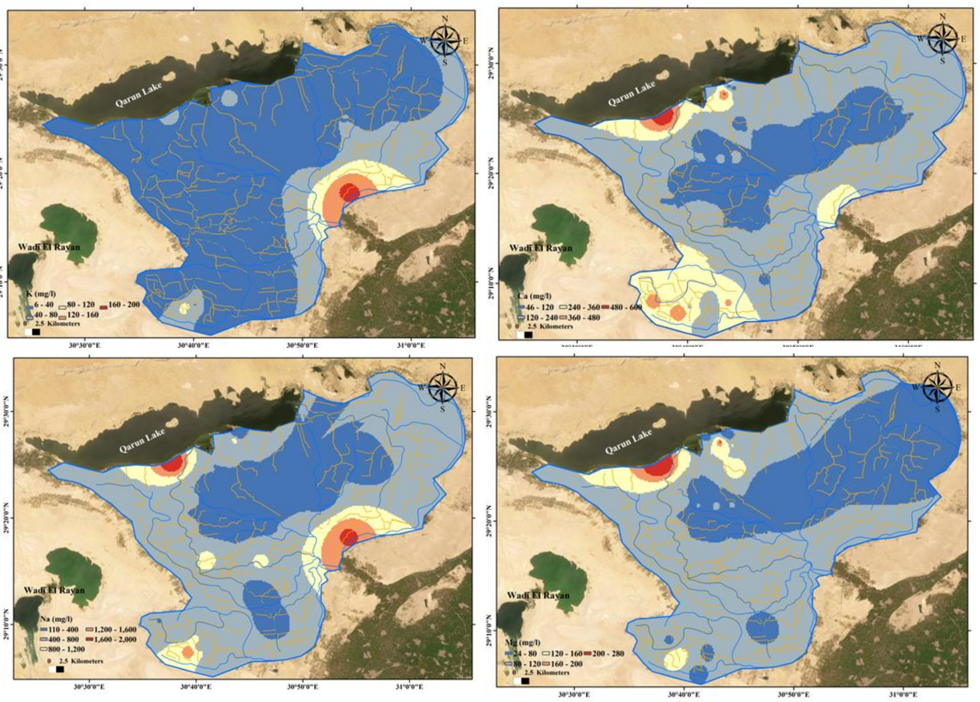


Fig. 4: Spatial distribution maps of major cations in the study area.

5.5 Spatial distribution of major anions

5.5.1 Distribution of chloride concentration

Chloride is also abundant anion where the concentration varies from 85 mg/l in (W13) to1992 mg/l in (W14) with an average of 665.15 mg/l (Table1) according to WHO 2011. The majority of groundwater samples in production wells have chloride content ranging from (300 to 1992 mg/l) with percentage of 68.42 % was recorded in Northern portion of study area. The presences of chloride ion with high concentration in groundwater reflect the presence of evaporate salts rich in chloride.Chloride content shows increase from north east to north west direction(Fig.5).

5.5.2 Distribution of bicarbonate concentration

Bicarbonate is the most dominant anion in the area which ranges from 72 mg/l in (W9) to 787 mg/l in (W26) with an average of 393.64 mg/l (Table1) according to WHO 2011. The majority of collected groundwater samples have bicarbonate content ranging from 250 to 500 mg/lwith percentage of 76.31% of collected samples.Bicarbonate content shows increase from north to south direction (Fig.5).

5.5.3 Distribution of sulphate concentration

Sulphate is also abundant anion where the concentration varies from 51.6 mg/l in (W18) to 3370.2 mg/l in (W14) with an average of 751.13 mg/l (Table1) according to WHO 2011. The high contents of sulphate ranging from 300 to 3370.2 mg/l with percentage of 57.89 % representing the southern parts of the study area. Sulphate content shows increase from south to north direction (Fig.5). This reflects effect of downward seepage of sanitary and agricultural waste water rich with sulfates, and to local terrestrial source of sulfate as gypsum.

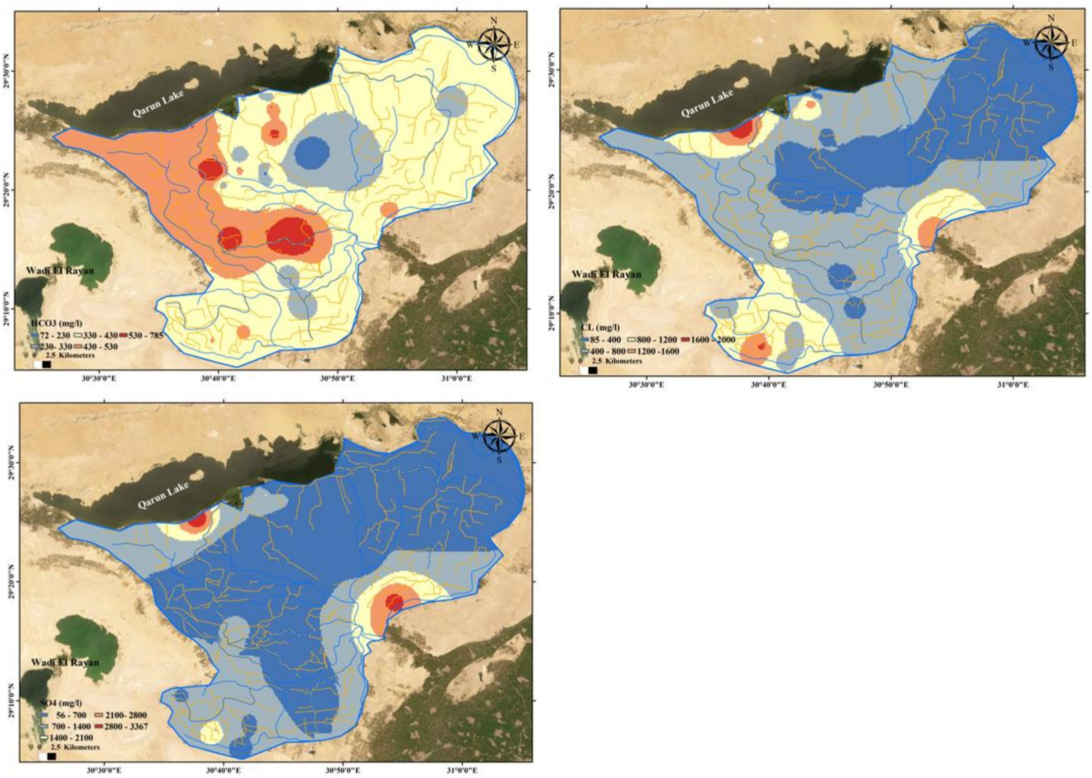
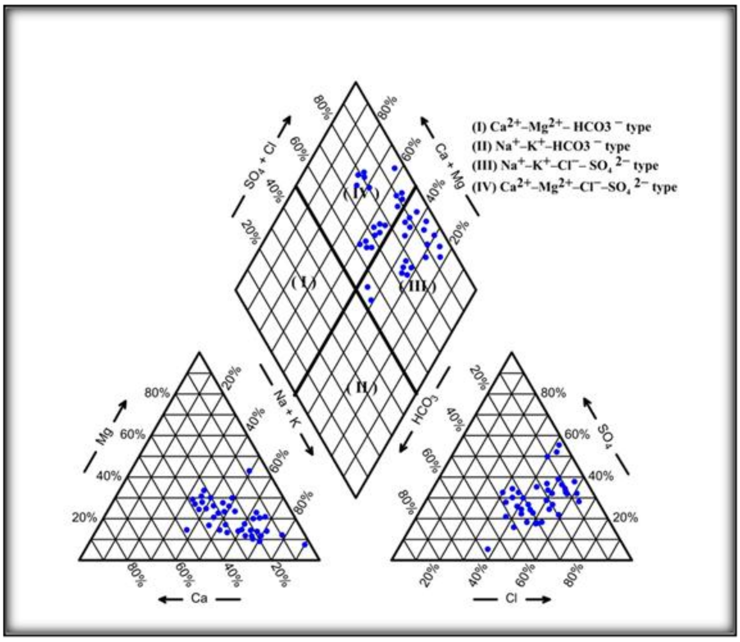


Fig. 5: Spatial distribution maps of major anions in the study area.

6. Geochemical controlling mechanisms and water facies

The Piper diagram (Piper 1944) is a commonly used and very effective method for classifying water chemical types based on the basic geochemical characteristics of major ions. The chemical data for the ground water samples collected from the study area are plotted in a Piper diagram (Fig.6).

The geochemical classification of groundwater is based on ion relationships, the most common are the tri-linear diagram of Piper (1944). Piper's tri-linear diagram for groundwater wells consequently show that most of water chemical compositions are plotted in different areas (38 well). NaCl and $NaHCO_3$ water type.



(Fig.6): Piper tri-linear diagram for groundwater samples of the Quaternary aquifer in the study area.

According to piper diagram, the Quaternary aquifer of the study area has two main water types, NaCl and $NaHCO_3$ water type which reveal initial phase or groundwater mineralization.

According to **Schoeller's** semi logarithmic graphs **(1967),** ion sequences ordering of shallow groundwater samples are presented in (Table2) and (Fig7). The majority of groundwater samples have ion sequence ordering (Na^{+} > Mg^{2+} > Ca^{2+}) / (HCO_3^{-} > Cl^{-} > SO_4^{2-}). Dominance of sodium cation over calcium and magnesium and bicarbonate over chloride and sulphate as anion in the majority of samples reflected that the predominance of sodium carbonate water types. The presence of sodium bicarbonate in majority samples reflected the effect of recent recharge.

Table (2): Ion sequence of groundwater samples of the Quaternary aquifer in the study area.

Ion sequence	Wells No.	Sequence NO.	Sequence %
NaCl	**3, 4, 5, 6, 7, 9, 14, 15, 16, 19, 20, 21, 23, 24, 25,28,29,30,31,32,33,35,36,38.**	**24**	**63.16 %**
$NaHCO_3$	**1, 8, 10, 12,13,18,22**	**7**	**18.42 %**

Na_2SO_4	**11,27,34,37**		**4**	**10.53%**
$CaCl_2$	**2,17**		**2**	**5.26 %**
KCl	**26**		**1**	**2.63%**
Total		**38**	**38**	**100 %**

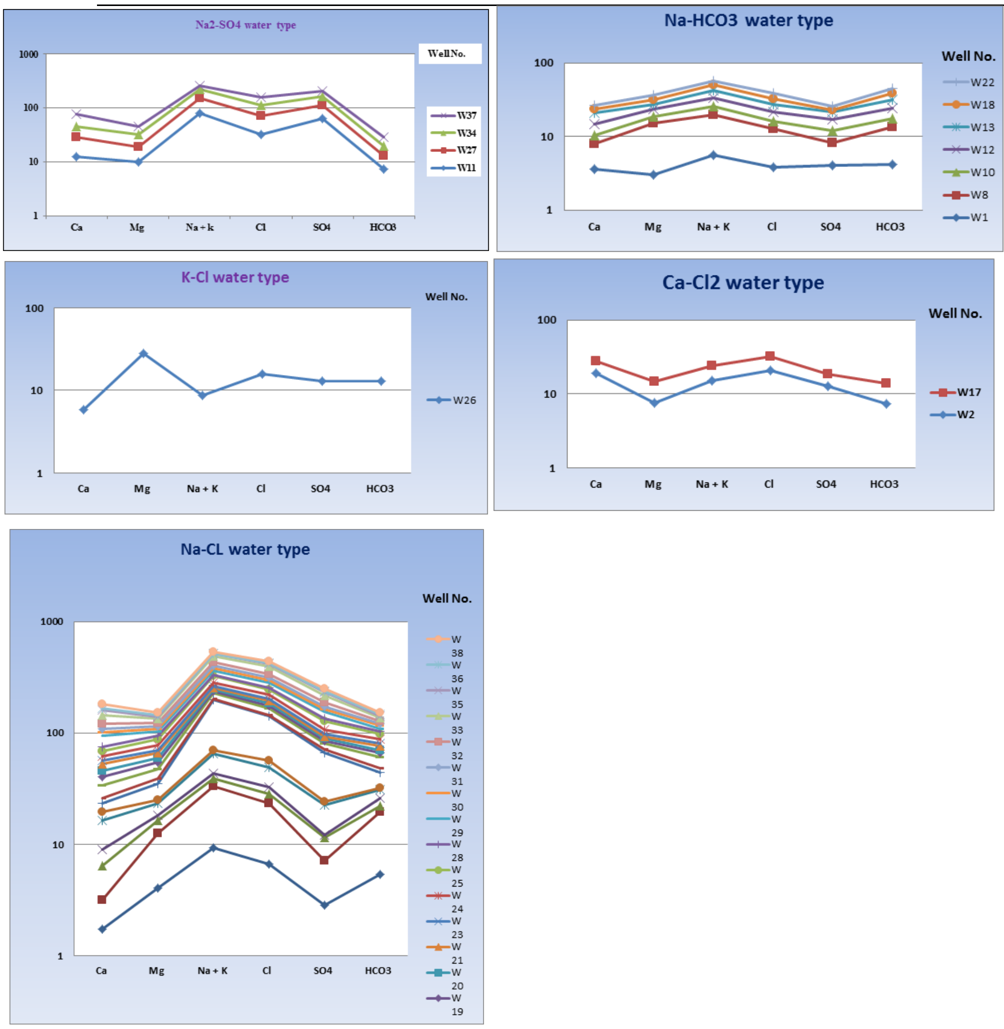


Fig.7: Groundwater types according to Schoeller 1967.

CONCLUSION

The groundwater in the study area has been evaluated for its chemical composition and suitability for agricultural purposes. The main anion of groundwater in the study area is Cl^- , and the main cation is Na^+. The ions of Cl^-, SO_4^{2-}, Mg^{2+}, Na^+, and K^+ have agreat influence on the salinity concentration. The main water chemistry type is NaCl which accounted for 63.16 %of water samples. The groundwater of the study area indicated slightly alkaline to alkaline, hard to very hard conditions, while major cations are in the order of: $Na^{+}>Mg^{2+}>Ca^{2+}>K^{+}$and the major anions are in the order of:$HCO_3^{-}>Cl^{-}>SO_4^{2-}$. According to piper the water types are (1) Na^{+}- K^{+}- Cl^{-}- SO_4^{2-} , (2) Ca^{2+}- Mg^{2+}-Cl^{-}- SO_4^{2-}. Dominance of sodium cation over calcium and magnesium and bicarbonate over chloride and sulphate as anion in the majority of samples reflected that the predominance of sodium carbonate water types. The presence of sodium bicarbonate in majority samples reflected the effect of recent recharge.

REFRENCES:

Ahmed, M.A., 2012. Assessment of intrinsic vulnerability to contamination for the alluvial aquifer in El-Fayoum Depression Using the DRASTIC method. J. Radiate. Res. Appl. Sci. 5 (4), 743–768.

Ali, R.R., Abdel Kawy, W.A.M., 2012. Land degradation risk assessment of El Fayoum depression, Egypt Arab. J. Geosci. https://doi.org/10.1007/s12517-012-0524-7.

Baioumy, H.M., Kayanne, H., Tada, R., 2010. Reconstruction of lake level and climate changes in Lake Qarun, Egypt, during the last 7000 years. J. Great Lakes Res. 36, 318–327.

Mohamed A. Dawoud, Madiha M.Darwish and Mona M. El-Kady (2005). "GIS-Based Groundwater Management Model for Western Nile Delta" Research Institute for Groundwater, NWRC, Egypt; pp.585–604.

Piper, A. M. (1944). "A graphic procedure in the geochemical interpretation of water analysis" Am. Geophys. Union. Trans., Vol.25, pp. 914-923.

Schoeller, H., (1967). "Geochemistry of Ground Water. An International Guide for Research and Practice", UNESCO, Vol. 15, pp. 1-18.

Van Zon, H.C.J., Jeanes, K.W., 1992. Environmental Profile, Fayoum Governorate, Egypt.Euroconsult/Darawish Consulting Engineers, for Netherlands Directorate General for Cooperation and Fayoum Environmental Affairs Department.

World Health Organization (WHO), (2011). "Guidelines for Drinking Water Quality", health criteria and other supporting information, pp. 940 - 949.