Assessment of groundwater Quality for irrigation Suitability in El Fayoum Depression Western Desert, Egypt

Mohamed Ezzat[1], Mobarak H. Aly[2], Mamdouh El Hattab[2], Mohamed Gad[2]

1- Environmental Sciences University of Sadat City.

2- Environmental Studies& Researches Institute University of Sadat City

ABSTRACT

Groundwater in El Fayoum governorate has a particular importance where it is the source for fresh water used for agricultural purposes. Thirty-eight groundwater wells were collected during summer 2017 and were analysis for chemical characteristics. These data has been used to preliminary evaluation of suitability of groundwater for irrigation purposes using groundwater quality indices which are TDS, RSC, TH, PI, MH, CAI and CR. The TDS in groundwater varied between 614.3 and 8950 with an average value of 4782.15. The RSC in groundwater varied between -37.74 mg/l and -1.41 mg/l with an average value of -19.575 mg/l. The TH values of the study area varied between 256.4 and 2658.8 with an average value of 1457.6. The PI of the groundwater samples varied between 42.46 and 92.83 mg/l with an average value of 67.645 mg/l. The MH values of the study area varied between 28.42 and 73.42 mg/l with an average value of 50.92 mg/l. The CAI values of the study area varied between -1.49 and 0.3 with an average value of -0.595. The C.R values of the study area varied between 3.08 and 335.08 with an average value of 169.08.

Key words: Physicochemical parameters, Water Quality, Irrigation indices, El Fayoum Depression, Egypt

الملخص

المياه الجوفية في منطقة الفيوم لها أهمية خاصة حيث أنها مصدر المياه العذبة المستخدمة للأغراض الزراعية. وقد تم تجميع 38عينة مياه جوفية خلال فترة صيف 2017 وخضعت لتحليل الخصائص الكيميائية ، وتم استخدام هذه البيانات لتقييم ملاءمة المياه الجوفية لأغراض الري باستخدام مؤشرات جودة المياه الجوفية وهي TDS CR, CAI, MH, PI, TH, RSC، . تتراوح قيمة TDS من 614.3 الي 8950 ملليجرام/ لتر بمتوسط 4782.15 ملليجرام/ لتر. تتراوح قيمة RSC من -37.74 الي 1.14 ملليجرام / لتر بمتوسط -19.57 ملليجرام /لتر. تتراوح قيمة TH من 256.4 الي 2658.8 ملليجرام/ لتر بمتوسط 1457.6 ملليجرام/ لتر. تتراوح قيمة PI من 42.46 الي 92.83 مليجرام / لتر بمتوسط 67.64 ملليجرام/ لتر. تتراوح قيمة MH من 28.42 الي 73.42 مليجرام / لتر بمتوسط 50.92 ملليجرام/ لتر. تتراوح قيمة CAI من -1.49 الي 0.3

مليجـرام/ لتـر بمتوسـط -0.595 مليجـرام / لتـر. تتـراوح قيمـة CR مـن 3.08 الـي 335.08 بمتوسـط 169.08 ملليجرام/ لتر.

الكلمات الدالة : الخصائص الفيزيائية والكيميائية ، جودة المياة ، مؤشرات الزراعة ، منخفض الفيوم ، مصر.

INTRODUCTION

Groundwater in El Fayoum area has a particular importance where it is the source for fresh water used for agricultural purposes (Mohamed A. Dawoud et al., 2005). Groundwater resources of El Fayoum, Egypt face a very serious problem which is contamination from agricultural and urbanization activities.

The objective of this work is to evaluate groundwater quality where upon can determine its suitability for irrigation uses through certain parameters which are TDS, RSC, TH, PI, MH, CAI and CR.

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.

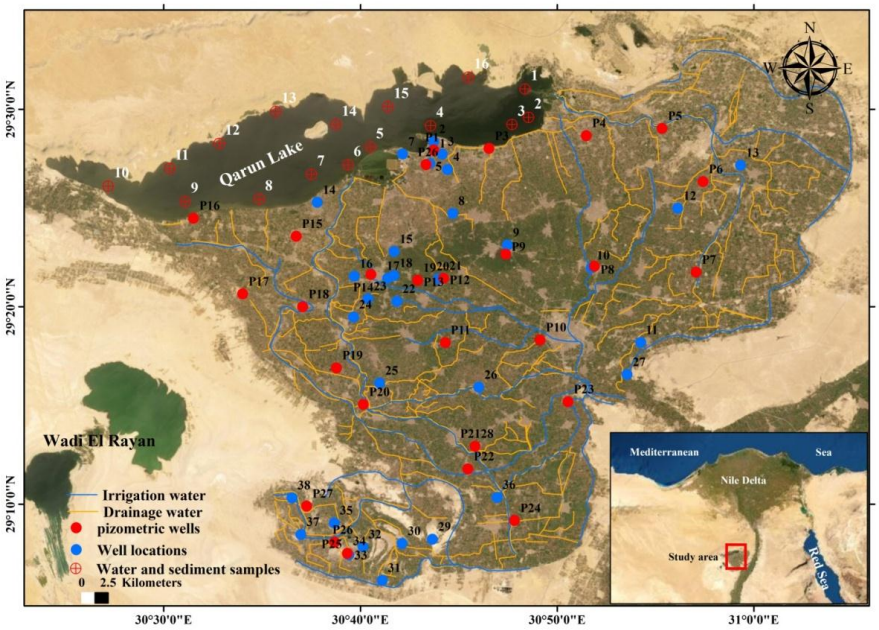

Fig.1. Location of the study area and measuring points.

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 **47 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).

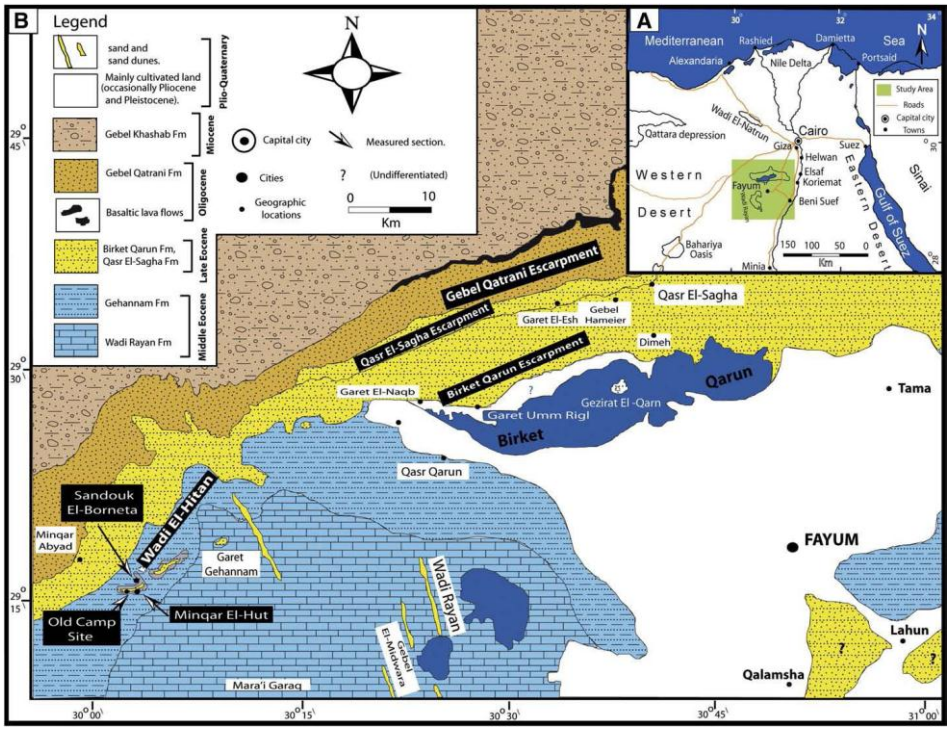

Fig.2.Geological map of El-Fayoum and its adjacent area (Ahmed, 2012).

4. METHODOLOGY

4.1. Determining groundwater quality indices

Some physicochemical parameters related to groundwater quality were investigated in this attempt to assess suitability of groundwater for the purpose of irrigation as follows.

4.1.1 Total Dissolved Solids (TDS)

Total dissolved solids (TDS), is defined as the concentration of all dissolved minerals in the water. The concentration of TDS in natural water is usually less than **500** mg per liter, while more than **500** mg per liter is undesirable for drinking and many industrial uses. TDS value of **500** mg per liter as the desirable limit and **2000** mg per liter as the maximum permissible limits (Jain, C. K, Kumar, C. P., Sharma, M. K., 2003).

4.1.2 Residual Sodium Carbonate (RSC)

The excess sum of carbonate and bicarbonate in groundwater over the sum of calcium and magnesium also influences the unsuitability of groundwater for irrigation. This is denoted as residual sodium carbonate (RSC), which is calculated as following equation (Guan, W., Chamberlain, R. H., Sabol, B. M., Doering, P. H., 1999):

$$\mathbf{RSC = (CO_3 + HCO_3) - (Ca + Mg)} \qquad (3)$$

Where the concentrations are reported in meq/l. RSC has been calculated to determine the hazardous effect of Co_3^{2-} and HCO_3^- on the quality of water for agricultural purpose. The classification above means that wells have RSC <1.25 are safe for irrigation, it is considered unsuitable if it is greater than 2.5 (Guan, W., Chamberlain, R. H., Sabol, B. M., Doering, P. H., 1999), Ramesh, K., Elango, L., (2011).

4.1.3 Permeability Index (PI)

The permeability index (PI) values also indicate that the groundwater is suitable for irrigation. The soil permeability is affected by the long term use of irrigation water as it is influenced by Na^+, Ca^{2+}, Mg^{2+} and HCO_3^- content of the soil. Permeability index formula has

been evolved by (Doneen, 1964), to measure the soil permeability for assessing the suitability of water for irrigation purposes as follows.

$$\mathbf{PI} = \frac{(Na+\sqrt{HCO3})}{(Ca+Mg+Na)} \times 100 \quad (4)$$

Accordingly, the PI is classified under class I (>75%), class II (25‑75%) and class III (< 25%) orders.

4.1.4 Magnesium Hazard (MH)

Generally, alkaline earths are in equilibrium state in groundwater. In other words, Ca^{+2} and Mg^{+} maintain a state of equilibrium in groundwater. More Mg^{+2} present in waters affect the soil quality converting it to alkaline and decreases crop yield (Ramesh, K., Elango, L., (2011), (Doneen, 1964)). Szabolcs and Darab (1964) proposed MH value for irrigation water as given by the following formula (where the concentrations are expressed in mg/l):

$$\mathbf{MH} = \frac{(Mg)}{(Ca+Mg)} \times 100 \quad \mathbf{(5)}$$

MH values > 50 are considered harmful and unsuitable for irrigation purposes, (Szabolcs, I.; Darab, C (1964).

4.1.5 Total Hardness (TH)

Hardness is defined as water that is rich in calcium (Ca^{+2}) and/or magnesium (Mg^{+2}). Probably the most common problem identified with groundwater quality is that of hardness (Todd, D., (1980)).

The TH of the groundwater was calculated using the formula given below (Ragunath, H. M., (1987), Hem, J. D., (1985)).

$$\mathbf{TH = (CaCo_3)\ mg/l = (Ca^{+2} + Mg^{+2})\ mg/l \times 50} \quad \mathbf{(7)}$$

According to Todd 1980 (Todd, D., (1980)), total hardness is customarily expressed as the equivalent of calcium carbonate. Thus,

$$\mathbf{TH = Ca} \times \frac{CaCo3}{Ca} \times Mg \times \frac{CaCo3}{Ca} \quad \mathbf{(8)}$$

Where TH, Ca, and Mg are measured in milligrams per liter and the ratios in equivalent weights Equation (8) reduce to

$$\mathbf{TH = 2.5Ca + 4.1Mg} \quad \mathbf{(9)}$$

The degree of hardness in water is commonly based on the classification from 0-75are Soft, from 75-150areModerately Hard, from 150-300are Hard and over 300are very Hard, (Sawyer, C. N., McCarty D. L., (1967)).

4.1.6 Chloro Alkaline Indices (CAI)

Schoeller (1967) has evolved a formula, Chloro alkaline indices (CAI) to know the ion exchange between the groundwater and its surroundings during residence or travelling in the aquifer. The CAI can be measured as

$$\mathbf{CAI} = \frac{(Cl-(Na+K))}{Cl} \qquad \mathbf{(10)}$$

Where, all ionic concentrations are expressed in terms of mg/l. The negative value of CAI indicates that there is exchange between sodium and potassium ($Na^{+}+K^{+}$) in water with calcium and magnesium (Ca^{+2} +Mg^{+2}) in the rocks by a type of base-exchange reactions. The positive value of CAI represents the absence of base-exchange reactions and existence of cation-anion exchange type of reactions.

4.1.7 Corrosively Ratio (CR)

The corrosively ratio is important to know whether the water can be transported in metallic pipes or not. The groundwater with corrosively ratio < 1 is considered to be safe for transport of water in any type of pipes, whereas >1 indicate corrosive nature and hence not to be transported through metal pipes (Raman, V., (1985)). The corrosively ratio is calculated using a formula as follows.

$$\mathbf{CR}=\frac{\frac{Cl}{35.5}+2\left(\frac{SO4}{96}\right)}{2\left(\frac{HCO3+CO3}{100}\right)} \qquad \mathbf{(11)}$$

The intensity of corrosion depends upon certain physical factors like temperature, pressure and velocity of flow of water. In addition to higher concentration of Cl^{-} and So_4^{2-} also increase the corrosion rate (Mahadevaswamy, G., Nagaraju, D., Siddalingamurthy, S., Lakshmamma, lone, M. S., Nagesh, P. C., Rao, K., (2011)).

5. RESULTS AND DISCUSSION

5.1 Evaluation of groundwater quality for irrigational purposes:

In El Fayoum area, the agriculture activities depend strongly on groundwater as a main source in irrigation. The irrigation water quality indices as TDS, RSC, PI, TH, MH, CAI and CR. were used to evaluate groundwater quality and its suitability for irrigational purposes.

The TDS distribution map (Fig.3) indicated that groundwater salinity varies from **614 to 8950** mg/l. The majorities of samples about 65.78 % have TDS less than **3000** mg/l, and is suitable for irrigation; whereas **13** wells (about **34.22 %**) have TDS more than **3000** mg/l and its water is unfit for irrigation as shown in table1.

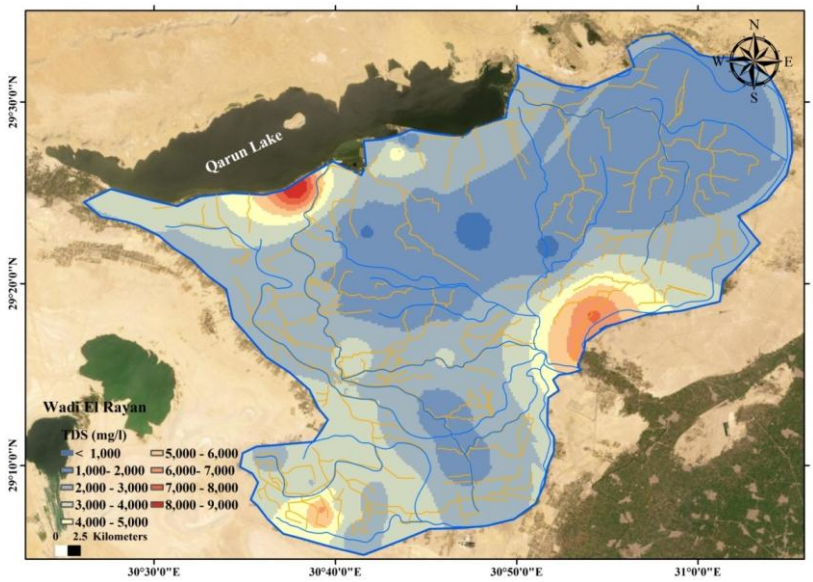

Fig.3: Salinity distribution contour map of production wells.

Table1: Classification of groundwater sample for irrigation use on the basic of TDS, RSC, PI, MH, TH, CAI, CR.

Parameters	Parameters Range	Water class	Water class Samples (%)
TDS	**< 200**	**Low**	**0%**
	200 -500	**Medium**	**0%**
	500 – 1500	**High**	42.1%
	1500 – 9000	**Very High**	**57.89%**
RSC	**<1.25**	**Good**	**100%**
	1.25–2.5	**Doubtful**	**0%**

	>2.5	**Unsuitable**	**0%**
PI	**>75**	**Class-I**	**10.52%**
	25–75	**Class-II**	**89.47%**
	<25	**Class-III**	**0%**
MH	**<50**	**Suitable**	**57.89%**
	>50	**Harmful and Unsuitable**	**42.10%**
TH	**<75**	**Soft**	**0%**
	75–150	**Moderately hard**	**0%**
	150–300	**Hard**	**0%**
	>300	**Very hard**	**100%**
CAI		**Negative**	**68.42%**
		Positive	**31.57%**
CR	**< 1**	**Noncorrosive**	**3%**
	>1	**Corrosive**	**97%**

The TDS in groundwater varied between 614.3 and 8950 with an average value of 4782.15. The RSC in groundwater varied between -37.74 mg/l and -1.41 mg/l with an average value of -19.575 mg/l. The TH values of the study area varied between 256.4 and 2658.8 with an average value of 1457.6. The PI of the groundwater samples varied between 42.46 and 92.83 mg/l with an average value of 67.645 mg/l. The MH values of the study area varied between 28.42 and 73.42 mg/l with an average value of 50.92 mg/l. The CAI values of the study area varied between -1.49 and 0.3 with an average value of -0.595. The C.R values of the study area varied between 3.08 and 335.08 with an average value of 169.08.

6. CONCLUSION

Data of **38** Groundwater wells during **summer 2017** has been collected and categories for irrigation. Then, seven criteria were used to evaluate groundwater quality and its suitability for irrigational purposes. These criteria are TDS, RSC, PI, TH, MH, CAI and CR. Groundwater wells were classified according TDS as about **57.89%** of wells have TDS more than **1500** mg/l, thus groundwater is suitable for irrigation. **100%** of wells are good and suitable for irrigation according to RSC. According to MH 57.89% of groundwater samples are Suitable for

irrigation. According to TH 100% of groundwater samples are hard. According to CR about 97% of groundwater samples are corrosive. According to the previous results the majority of groundwater samples are suitable for irrigation.

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