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Study of Groundwater Quality in El-Kharga Oasis, Western Desert, Egypt

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Abstract: In El-Kharga Oasis, Egypt, the groundwater is considered the sole source for water and it is used for different purposes. The present paper tries to assess groundwater suitability for different uses in El-Kharga oasis. The goal is to evaluate the suitability of the selected groundwater wells for irrigation and drinking, define the water types and investigate possible long and short term impact on groundwater quality. Fifteen water samples were collected from different wells. Parameters such as electrical conductivity (EC), pH, Total Dissolved Solids (TDS), temperature and other physical properties were recorded in the field. Major anions and cations were analysed in the laboratory. Chemical results suggest that the water type in the area varies predominantly from Na-HCO_3, to Na-Cl (Piper diagram). According to the EC and SAR calculation (Wilcox diagram) the most dominant classes (C2-S1 and C3-S1) were found. Salinity hazard in 60% of water samples is regarded as medium while in 40% of water samples is classified as high. In respect of all evaluating criteria, groundwater of all the 15 wells can be safely used for irrigation and drinking purposes.

Key words: Groundwater evaluation, major ions, water type, El-Kharga, Egypt.

Introduction

Interest in water analysis is due to the enormous importance of water to all categories of living beings. It is necessary for the healthy development of man, animals and plants. Developing countries are witnessing changes in groundwater which constitute an important source of potable water. The preference for groundwater to surface water is due to requirement of purification of the latter prior to distribution (Adeyeye and Abulude, 2004). The physical and chemical parameters of groundwater play a significant role in classifying and assessing water quality. Considering the individual or paired ionic concentration, certain indices to find the alkali hazards were proposed (Kelley, 1940; Wilcox, 1948; Eaton, 1950).

Groundwater in El-Kharga oasis is withdrawing from both shallow and deep artesian wells. Nearly all the wells originally over-flowed, but with the exploitation of groundwater from deep wells for irrigation, beginning 1959, the natural flows declined as more and more closely spaced deep wells were drilled. By 1975, all the deep wells had ceased to flow (Philip et al., 1985).

The objective of the present work is to discuss the major ion chemistry of the groundwater in El-Kharga oasis, Egypt and to evaluate the water suitability for different uses.

Materials and Methods

Study Area

The investigated area lies in the central part of the Western Desert (Figure 1). It covers an area of about 1600 km^2. It is located at 140 km to the east of El-Dakhla oasis and 220 km south of Assiut City. It is bounded by long 30° 20′ and 30° 40′ E and lat. 25° 05′ and 25° 30′ N. El-

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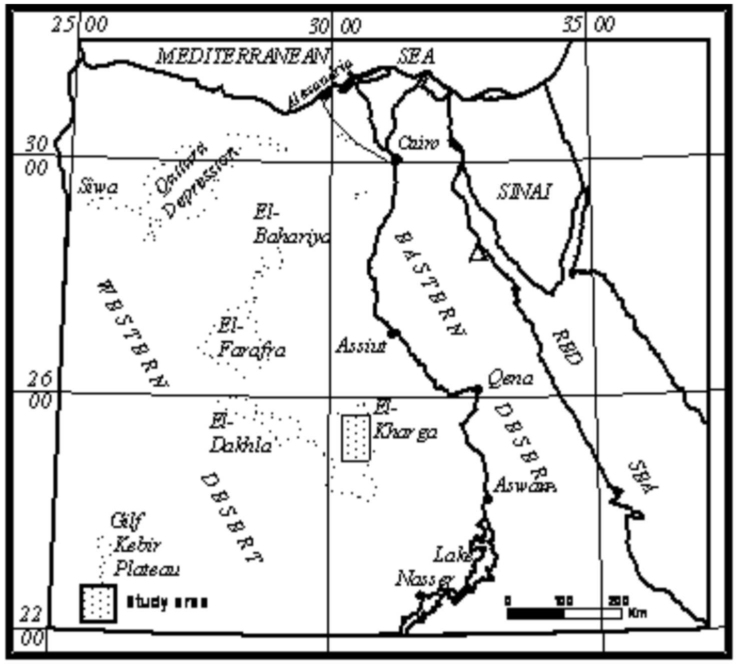

Figure 1: Location map of the study area.

Kharga depression has the same climatic characteristics of the Western Desert.

The climate of El-Kharga is arid, rainfall is sporadic, and temperatures are hot during the summer. In the spring, high winds and wind storms are common with sand storms and moving sand forming barchan dunes and drifts. Mean annual rainfall for Kharga is less than 1 mm. However, on rare occasions, torrential storms occur. The hottest month is July, with daily maximum and minimum of about 40 ^{o}C and 20 ^{o}C respectively (Diab, 1978).

Water Samples and Analyses

Groundwater samples were collected from 15 wells in El-Kharga oasis in June 2009.

The following physico-chemical properties were determined immediately after sampling: temperature, pH and electrical conductively. pH was measured with a meter (HANNA Model HI-9321) and conductivity measured with a JENWAY model 4310 conductivity meter after standardizing with KCL and NaCl solutions. Various standard methods (APHA, 1995) were used for other parameters. Anions by Ion Chromatography (IC) Model DX-500, total hardness were measured by EDTA titration using erichrome Black T indicator. All analyses were carried in triplicates. Means, standard deviation and coefficient of variation (%) of all the values were calculated. The data are presented in the form of graphs. Piper and Wilcox diagrams were used for representing and comparing the water quality using Aqua Chem 4.0 software.

Results and Discussions

Hydrochemistry

The in-situ measured temperature for the groundwater samples ranged from 29.9 to 38.3^{o}C. The variations in the recorded temperature for all the wells in the study area were mainly a result of the depth at which the well emerged (Al-Khashman, 2007). pH was in the range of 6.53 to 8.00 (Table 1). The highest desirable level for pH is within the range of 6.5–8.5 (WHO, 1990).

The electrical conductivity (EC) of the groundwater in the study area ranged from 377 µs/cm in Boulaq well 5 to 1060 µs/cm in Boulaq well 25 with an average value of 723 µs/cm at 25^{o}C. However, the high conductivity of the groundwater samples in some locations (corresponding to the highest of dominant ions) results from ion exchange and solubility of rocks in aquifer (Virkutyte and Sillanpaa, 2006).

Total Dissolved Solid (TDS) values in the water from wells varied from 227 mg/l in Boulaq well 5 to 636 mg/l in Boulaq well 25 (Table 1). In general, all the TDS values of the groundwater fall within the permissible limit of WHO standards for drinking water (Kelly, 1940).

According to Peavy et al. (1986), water can be classified on the basis of hardness into four categories:

Table 1: The physico-chemical parameters in the study area

Well	*Temp. °C*	*pH*	*EC µs/cm*	*TDS mg/l*	*Total Hardness mg/l $CaCO_3$*
El Mounira 10	32.1	7.27	858.67	515.00	116.43
El-Mounira 11	30.4	7.14	597.20	358.67	104.23
El-Mounira 12	31.1	7.06	691.20	416.00	132.77
El-Sherka 1	36.1	6.53	546.00	326.67	110.00
El-Kharga 5	32	6.73	388.53	234.67	105.60
El-Kharga 17	32.2	7.30	941.00	565.00	137.00
El-Kharga 19	35.2	6.89	717.33	430.67	124.80
El-Kharga 24	30.3	6.53	506.00	404.67	147.77
El-Kharga 33	34.2	6.90	816.60	490.00	108.30
El-Boustan	29.9	6.57	653.00	392.00	209.33
Boulaq 5	38.3	7.05	377.53	227.33	87.53
Boulaq 20	36.4	7.50	1055.00	633.00	258.60
Boulaq 25	37.2	7.50	1060.00	636.00	269.60
Boulaq 29	36.7	8.00	1042.00	625.00	265.80
Paris 9	33.50	6.63	593.87	354.33	125.77
Average	33.71	7.04	722.93	440.60	153.57
Min	29.90	6.53	377.53	227.33	87.53
Max	38.30	8.00	1060.00	636.00	270

water having 0–50 mg/l $CaCO_3$ as soft, 50–150 mg/l $CaCO_3$ as moderately hard, 150–300 mg/l $CaCO_3$ as hard while samples having total hardness of over 300 mg/l $CaCO_3$ as very hard. Based on these, the degree of hardness of the studied groundwater was relatively high (Table 1) and this might encourage the dissolution of heavy metals (Adeyeye and Ayejuyo, 2002). Water hardness has no known adverse effects. However, hard water is unsuitable for domestic use. Depending on factors such as pH and alkalinity, a hardness of more than about 200 mg/l will lead to scale deposits in the piping system (Vander, 2003).

Calcium and Magnesium are primarily found in groundwater due to the dissolving of limestone (primarily composed of calcium carbonates). The dissolving of limestone occurs when the limestone reacts with rainwater which has become slightly acidic through a reaction with carbon dioxide. Calcium and Magnesium ions are also released when the water reacts with naturally occurring gypsum (Hem, 1989).

The calcium content of the water samples varied between 15.93 mg/l in El-Kharga well 5 and 59 mg/l in Boulaq well 20, with an average value of 29.4 mg/l (Figure 2). Magnesium concentration in groundwater wells ranged from 11 mg/l at Boulaq well 5 to 33 mg/l at Boulaq well 29 (Figure 2).

The concentration of sodium in the groundwater samples ranged from 20.9 mg/l in El-Kharga well 5 to 138 mg/l in El-Kharga well 17 (Figure 2). While the concentration of potassium ranged from 21 mg/l in El-Kharga well 17 to 46 in Boulaq well 20 (Figure 2). The recommended limit for sodium concentration in drinking water is 200 mg/l. A higher sodium intake may cause hypertension, congenial heart diseases and kidney problems (Singh et al., 2008).

Chloride was in the range of 46–207 mg/l (average, 108.2 mg/l) (Figure 3). The well 20 in Boulaq has highest chloride content compared to other sources. Chlorides are relatively harmless to organisms except when converted to Cl_2, ClO^- and ClO_3^- which are toxic. High chloride content impacts taste and could cause corrosion. Chloride is an essential element for plants and animals and also an important criterion for irrigation water. High amount of chloride is accumulated in the leaves. This process causes drying of leaves.

Sulphates are principally derived from the dissolving of minerals such as gypsum ($CaSO_4*2H_2O$) and anhydrite ($CaSO_4$). Secondary sources of sulphates are from the weathering of pyrite and the dissolving of ammonium sulphate fertilizers (Singh et al., 2008). The sulphate concentration in the groundwater varied between 11.3 mg/l in Boulaq well 5 and 142.3 mg/l in El-Boustan well, with an average value of 59.4 mg/l (Figure 3). Bicarbonate values in groundwater samples ranged from 78 mg/l in Boulaq well 20 to 282.3 mg/l in El-Mounira well 12 (Figure 3).

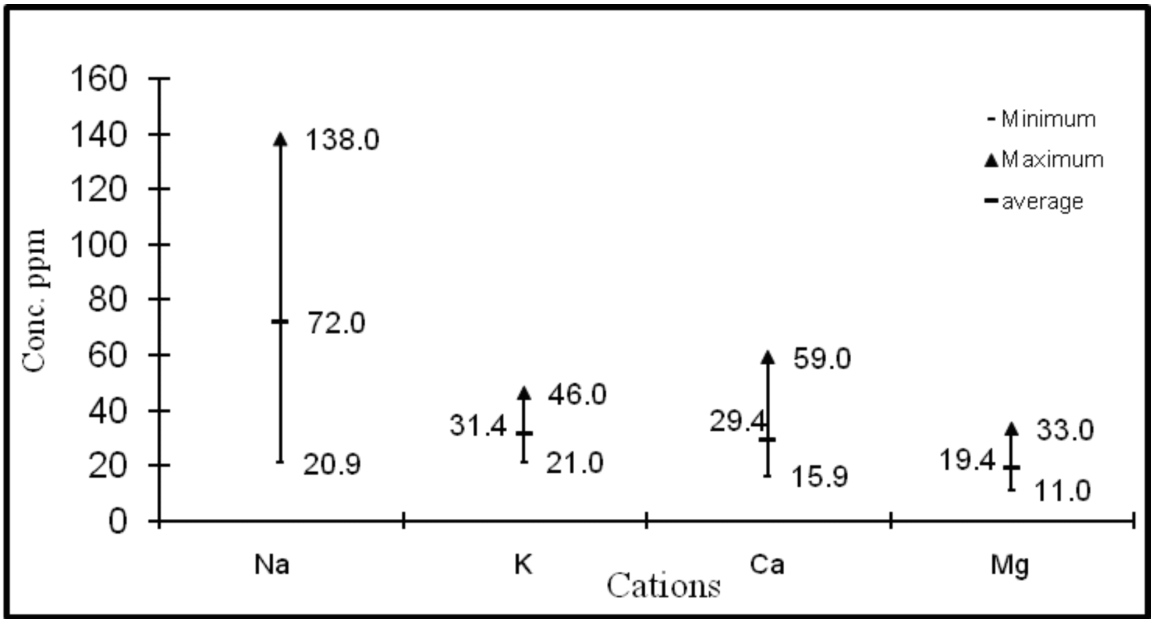

Figure 2: Minimum, maximum and average values for major cations.

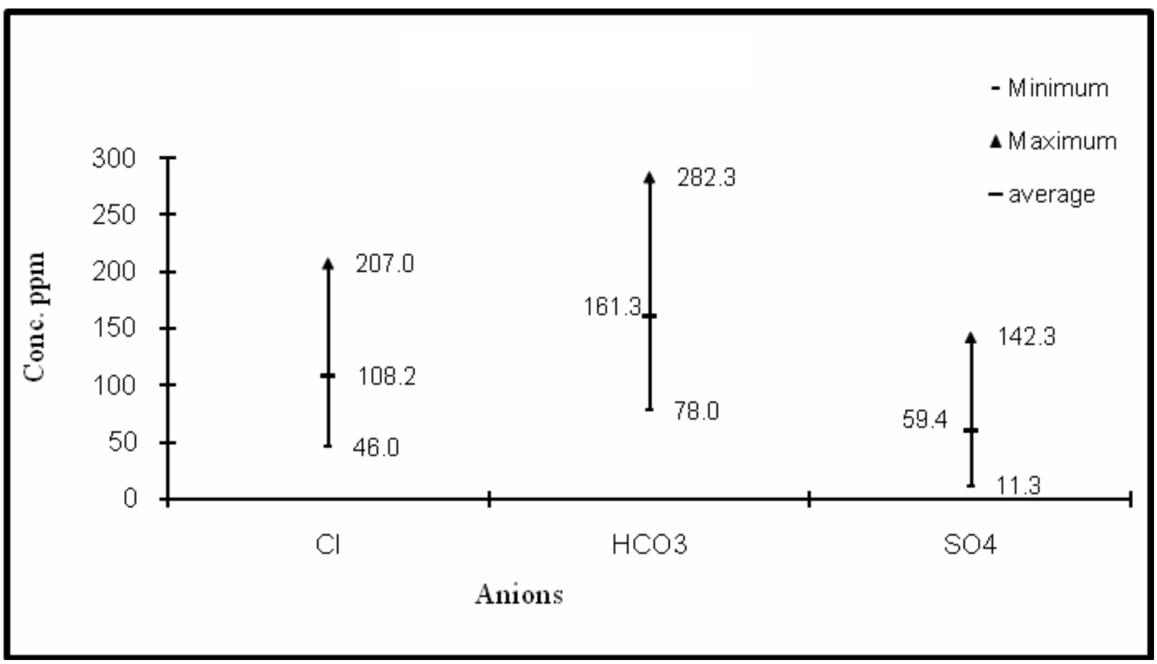

Figure 3: Minimum, maximum and average values for major anions.

Chemical Classification of Ground Water

Hill-Piper Diagram

One method of comparing the results of chemical analyses of groundwater is with a tri-linear diagram (Piper, 1953) (Figure 4). This diagram consists of two lower triangles that show the percentage distribution, on the milliequivalent basis, of the major cations (Mg^{2+}, Ca^{2+}, and Na^{+} plus K^{+}) and the major anions (Cl^{-}, SO_4^{2-} and CO_3^{2-} plus HCO_3^{-}) and a diamond-shaped part above that summarizes the dominant cations and anions to indicate the final water type. This classification system shows the anion and cation in terms of major-ion percentages. The water types are designated according to the area in which they occur on the diagram segments.

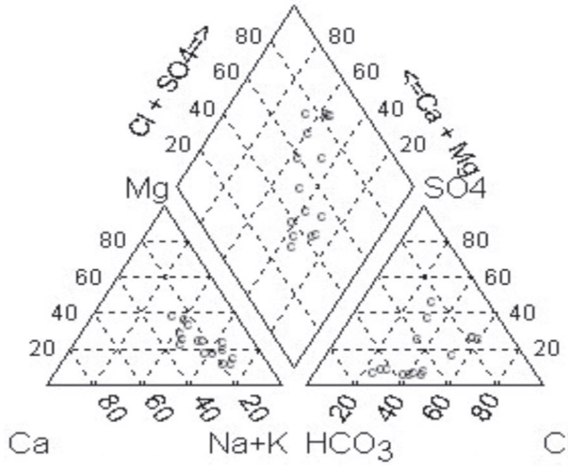

Figure 4: Piper diagram of groundwater quality of El-Kharga Oasis.

The cation distribution indicates that the samples range in composition from sodium/potassium to predominantly mixed cation. There is a small percentage of the groundwater that has a magnesium cation classification. In the anion triangle, there is a tendency toward bicarbonate/chloride type water to mixed anion-type water.

Groundwater Quality for Irrigation Purposes

The water quality refers to characteristics of water supply that will influence its suitability for specific use (Ayers and Westcot, 1985). The suitability of groundwater for irrigation purpose depends upon its mineral constituents. The following are the important characteristic properties of groundwater to determine its suitability for irrigation proposes.

Salinity

The most influential water quality guideline on crop productivity is the salinity hazard as measured by electrical conductivity (EC). Regarding TDS content, water is considered satisfactory when it contains lesser than 1000 mg/l, fair if it contains between 1000 to 2000 mg/l, and inferior when its salinity exceeds 2000 mg/l (Ayers and Westcot, 1985). According to data presented in Table 1, all sampling wells are considered suitable for irrigation uses.

Sodium Percentage (Na%)

Sodium percentage determines the ratio of sodium in total cations including sodium, potassium, calcium and magnesium. All concentration values are expressed in meq/l. The sodium percentage was calculated by Todd's (1980) method.

$$Na\% = \frac{Na}{Ca + K + Na + Mg}$$

Suitability classification of groundwater in the studied area for irrigation with respect to Na% was carried out according to Wilcox (1955) Table 2.

Table 2: Suitability classification of water for irrigation

Category	*Na%*
Good	20–40
Permissible	40–60
Doubtful	60–80

Source: Wilcox (1955)

Sodium percentage in the studied wells at El-Kharga oasis as shown in Table 3 varied between 20% and 64.8 %. All studied wells are classified as good to permissible with respect to Na% except 3 wells (El Mounira 10, El-Kharga 17, El-Kharga 33) which contain about 64% of its cations as sodium. High percentage of Na^+ with respect to other cations in irrigation water, causes deflocculating and impairing of soil permeability (Singh et al., 2008).

Sodium Adsorption Ratio (SAR)

Sodium adsorption ratio (SAR) is an important parameter for the determination of suitability of water for irrigation. The sodium hazard is typically expressed as the SAR. This index quantifies the proportion of sodium (Na^+) to calcium (Ca^{2+}) and magnesium (Mg^{2+}) ions in a sample. Sodium hazard of irrigation water can be well understood by knowing SAR.

There is a significant relationship between SAR values of irrigation water and the extent to which sodium is adsorbed by the soil. If the water used for irrigation is high in sodium and low in calcium, the cation-exchange complex may become saturated with sodium. This can destroy the soil structure owing to dispersion of clay particles.

The SAR values of each water sample were calculated by using Richard (1954) equation in which all concentration values are expressed as meq/l.

$$SAR = \frac{Na}{\sqrt{(Ca + Mg)/2}}$$

The calculated value of SAR in the study area ranges between 0.89 and 5.15 (Table 3). Data is plotted according to the US salinity diagram classification of irrigation water (USSL (1954) (Figure 5), in which EC is taken as salinity hazard and SAR is taken as alkalinity hazard. Forty percentage of the groundwater samples (El-Kharga 17, El-Kharga 33, El Mounira 10, Boulaq 25, Boulaq 29, Boulaq 20) fall in the C3-S1 quality with high salinity hazard and low sodium hazard and 60% of the samples (El-Mounira 11, El-Mounira 12, El-Sherka 1, El-Kharga 5, El-Kharga 19, El-Kharga 24, El-Boustan, Boulaq 5, Paris 9) lie in C2-S1-medium salinity hazard and low sodium hazard.

Table 3: Characterization of groundwater samples according to sodium ratio

Well	*SAR*	*Na %*	*RSC*
El Mounira 10	5.08	64.52	2.17
El-Mounira 11	3.36	56.18	1.86
El-Mounira 12	3.64	56.16	1.95
El-Sherka 1	2.42	46.84	0.98
El-Kharga 5	0.90	24.54	-0.62
El-Kharga 17	5.15	64.82	1.42
El-Kharga 19	3.28	53.79	0.80
El-Kharga 24	0.92	22.16	-1.54
El-Kharga 33	4.93	63.651	1.99
El-Boustan	0.89	20.01	-2.72
Boulaq 5	1.39	34.94	-0.04
Boulaq 20	2.06	34.24	-3.90
Boulaq 25	2.01	33.56	-3.96
Boulaq 29	1.81	31.38	-3.95
Paris 9	2.11	42.71	-0.93
Average	2.66	43.30	-0.43
Min	0.89	20.01	-3.96
Max	5.15	64.82	2.17

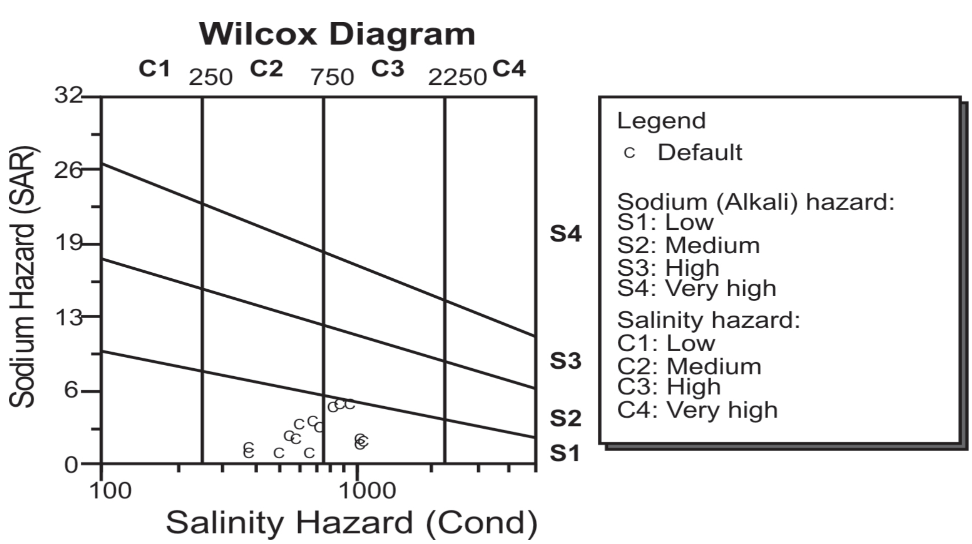

Figure 5: US Salinity classification of ground water in El-Kharga Oasis.

Residual Sodium Carbonate

Another way to examine the suitability of water for irrigation is to estimate the residual sodium carbonate (RSC) as suggested by Eaton (1950). The RSC has the following equation in which all concentration values are expressed as meq/l.

$$RSC = (CO_3^{2-}+HCO_3^{-})-(Ca^{2+}+Mg^{2+})$$

If the RSC >2.5 the water is not appropriate for irrigation. According to the RSC data represented in Table 3, the classification of groundwater quality for irrigation in the study area according to this criterion shows that all of the samples are below RSC value of 2.25. This indicates that water is suitable for irrigation.

Conclusion

According to previously presented data, the TDS values of the sampled wells ranges between (227.33 to 636 mg/l) which mean that all the studied wells fall within the permissible limit for salinity according to WHO standards for drinking water (WHO, 1990).

From the analysis of hydrochemical data the cation distribution indicates that the samples range in composition from sodium/potassium to predominantly mixed cation. There is a small percentage of the groundwater that has a magnesium cation classification. While the anion distribution show a tendency toward bicarbonate/chloride so the predominate water type in the area of study is Na^+/HCO_3^-, Cl^-.

The suitability of the studied wells for irrigation was carried out by Wilcox diagram in which EC is taken as salinity hazard and SAR is taken as alkalinity hazard which conclude that 40% of the groundwater samples have high salinity hazard and low sodium hazard and 60% of the samples have medium salinity hazard and low sodium hazard and so the studied wells at El-Kharga oasis are classified as (good to permissible) for irrigation uses.

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