Assiut J. Agric. Sci., 51 (1) 2020(125-149) *ISSN: 1110-0486*
Website: *www.aun.edu.eg/faculty_agriculture/journals_issues_form.php* ***E-mail: ajas@aun.edu.eg***

Groundwater Quality Assessment for Irrigation in West Edfu Region, Aswan, Egypt

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Received on: 3/2/2020 **Accepted for publication on:** 20/2/2020

Abstract:

The west Edfu area lies among of El-Galaba basin, which is considered an important part of the Egyptian 1.5 million feddans of the national reclamation project. This area attracted the investors for reclamation and development of new settlements. The groundwater is the only water source for such integrated development. Twelve groundwater samples were collected from west Edfu aquifer wells located in the western desert to evaluate the quality of these well waters for irrigation. The area under investigation is located between latitudes 24° 40' 00" – 25° 7' 22" N and longitudes 32° 32' 52" – 32° 50' 00" E. The groundwater chemical parameters (EC_w, TDS, pH, Na^+, K^+, Ca^{2+}, Mg^{2+}, Cl^- , HCO_3^-, Fe^{2+}, Pb and Cu^{2+}) of the investigated aquifer wells were determined. Irrigation indices such as total hardness (TH), sodium adsorption ratio (SAR), residual sodium carbonate (RSC), soluble sodium percentage (SSP), magnesium hazard (MH), residual sodium bicarbonate (RSCB), permeability index (PI), kelley's index (KI) were also evaluated. According to Ayers and Westcot, (1994), all the studied groundwater samples had pH values that are acceptable for irrigation. The concentration of the cations in these samples are decreased in the order of Na^+> Ca^{2+}> Mg^{2+}> K^+ and for anions was in the order of Cl^-> HCO_3^{2-}. The EC and TDS values of the groundwater samples ranged from 1680 to 9045 μS/cm and 870 to 4700 mg/L, respectively. The SAR of these samples varied from 5.31 to 8.91 meq/L. The PI, KI, SSP and MH differed from 42.90 to 71.49 %, 0.76 to 2.65, 46.59 to 77.78 % and 45.49 to 78.94 %, respectively. The concentration of both iron and copper of these groundwater samples is high in the eastern part of the study area while, the concentration of lead is high in the central part. In general, some well groundwater in the studied area is suitable for irrigation.

Keywords: *West Edfu, groundwater quality, western desert.*

Introduction

Aswan governorate which is located in Upper Egypt is considered one of the most promising developing areas. The governorate area is estimated by 62726 km² but the populated area does not exceed 2%. It is characterized by an arid climate with desert-like conditions. Although rainfall is not significant throughout the year, some rare and irregular storms take place over scattered localities during the winter season.

Groundwater accounts for 26% of global renewable fresh water resources (FAO 2003). Quality of groundwater is of paramount importance for irrigation in arid and semi-arid regions. Crop growth mainly depends on groundwater supply for irrigation in several arid and semi-arid areas. In fact, the suitability of groundwater for irrigation depends on the effects of constituent mineral elements of water on both the plant and soil (Richards 1954; Singh *et al.* 2009). Excessive amounts of dissolved ions in irrigation water affect plants and agricultural soils and thus reducing the productivity (Ravikumar *et al*., 2010). In Egypt, groundwater exists in the fringes of the Nile Valley, Nile Delta, Western Desert, and Sinai Peninsula. It is the only available resource for interdisciplinary development in the areas around the Nile Valley because of the insufficient rainfall. Groundwater of the Nile aquifer system and desert fringes is not a resource in itself as it is replenished from the river Nile by seepage from canals and deep percolation from irrigation application (El Arabi, 2012). Allam *et al*. (2002) reported that groundwater in the Western Desert is deep seated. Recent studies have indicated that it is not a renewable resource and use of this fossil water depends on the cost of pumping and potential economic return over a fixed time period.

The evaluation of groundwater resources for development requires an understanding of the hydrogeology and hydro geochemical properties of the aquifer. The development of groundwater resources in these arid and semi-arid regions is a sensitive issue, and careful management is required to avoid water-quality degradation (Trabelsi *et al*. 2007; Dassi 2010). Groundwater chemistry in an area is influenced by several processes like rock/soil-water interaction during recharge and groundwater flow, precipitation/dissolution of mineral species, prolonged storage in the aquifer, exchange, and adsorption/desorption gas resolution/dissolution (Hem 1985). Recent studies also showed that land use and urbanization also causes an impact on the hydrochemistry and hence there is a need for assessment and effective management of groundwater resources (Jeong, 2001). Generally, water quality parameters such as major cations (Na^+, Ca^{2+}, Mg^{2+} and K^+) and anions (Cl^-, SO_4^{2-} and HCO_3^-) and heavy metals are indicators of drinking water use. However, water quality indices such as sodium adsorption ratio (SAR), sodium percentage (SSP, %Na), residual sodium carbonate (RSC), residual alkalinity (RA), Kelly's ratio (KR) (or Kelly's index, KI), permeability index (PI), magnesium hazard (MH) (or magnesium adsorption ratio, MAR), total dissolved solids (TDS) and total hardness (TH) based on primary water quality parameters are frequently used to determine the quality of water for irrigation (Singh *et al.* 2013; Gautam *et al.* 2015). The aim of this work is to evaluate the groundwater properties and quality of west Edfu region and its suitability for irrigation. Further, the water quality parameters will be compared with those of the international standards.

Water Resources in Aswan Governorate

Water represents the main objective part in the sustainable development of an area. In Aswan governorate, the most important source of water is Nile River. The average annual natural flow of the Nile estimated at Aswan city is about 84 billion m3, of which 55.5 billion m3 represent Egypt's share, 18.5 billion m3 are Sudan's share, and the remainder is allowed for evaporation. High Aswan Dam provides storage to guarantee regulated water supplies (MWRI). The distribution of the groundwater aquifer which is stored in the bottom of the stone rock in EL-Shalal area and west Kom Ombo represent the backbone in the continuity of the sustainable projects. The groundwater levels recorded before and after the construction of the Aswan High Dam indicate that an increase in groundwater levels in the Valley and Delta occurred during the period of 1968 to 1978. The recorded total rise has been a maximum of 2 m in the Nile Valley and a maximum of 0.40 m in the Nile Delta. After 1978, the system has approached a steady-state condition. No significant regional changes could be attributed to the impacts of the Aswan High Dam in the groundwater regime. Groundwater underlying the Nile Valley and the Delta depends entirely on both deep percolation and seepage of irrigation water diverted from the Nile. Some limited renewable and non-renewable groundwater resources occur in the Nubian sandstone of the western desert (Sahara) and in Sinai (MWRI). The rainfall and floods do not represent a major source of water for a few quantities which fall in the winter. The bulk of water resources are used in the agriculture, which represents more than 85% and the rest include drinking water, health and industrial purposes.

Geological and topography settings:

Topography of the investigated area which represents a part of west Aswan is generally irregular. A number of small, shallow and dry wadies run towards the Nile and are mainly controlled by the ENE-WSW and E-W Fractures and by rock texture (El-Shazly *et al*., 1975). Also several isolated hills are present. Geologically, the Nubia formation of Cretaceous age (Issawi, 1981) which covers all the examined area and overlies the basement rocks, is mainly composed of sand and sandstone with clay and shale intercalations of irregular thicknesses (Fig.1). The structure of the area, which represents a part of West Aswan area, is dominated by ENE-WSW trending open folds of regional and local scale, while the fractures and faults have several trends and partly extend across long distances, some are short and grouped together in parallel arrangement accompanying the major fractures (El-Shazly *et al*., 1975).

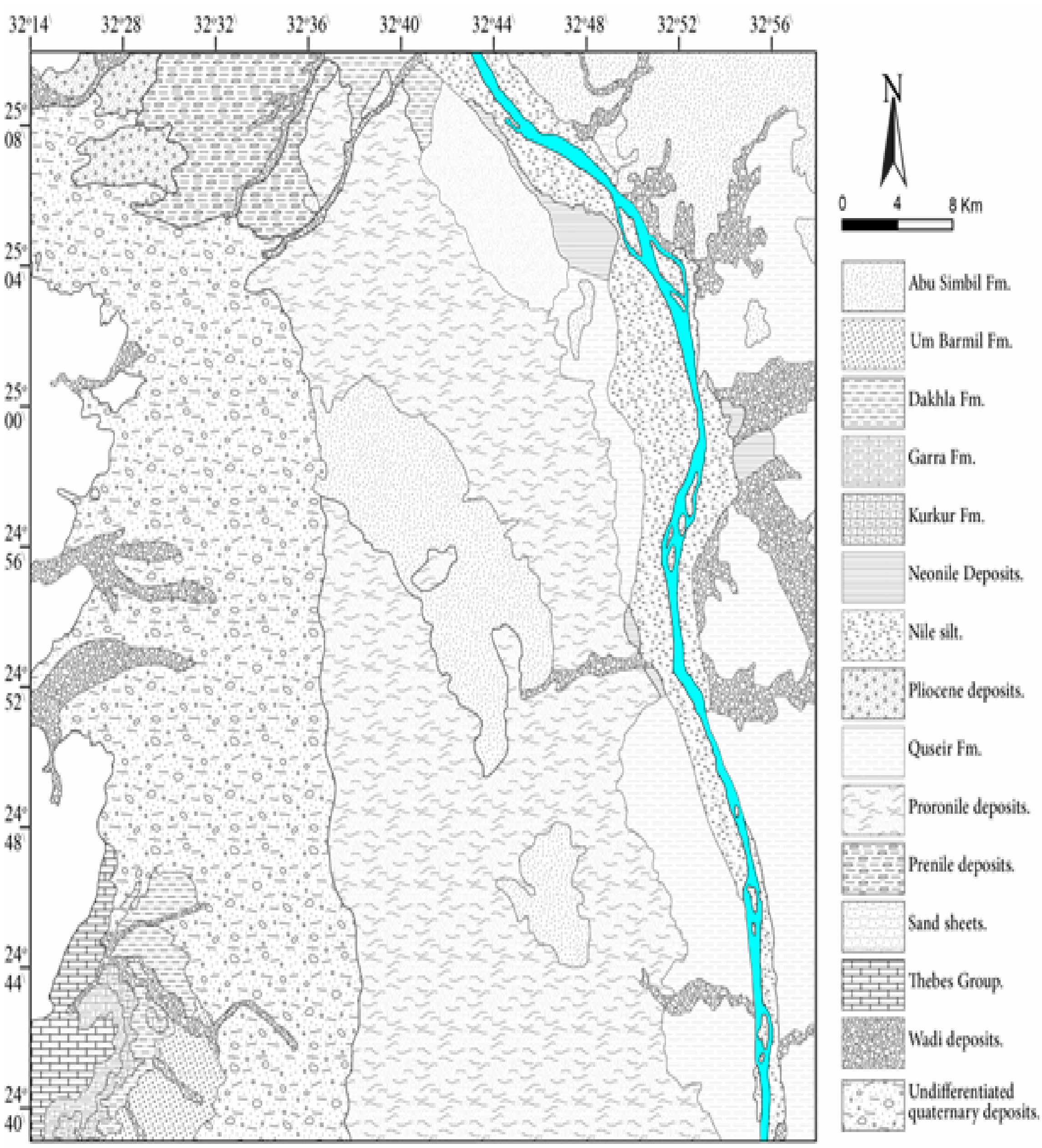

Fig. 1: A geological map of the west Edfu area.

Materials and Method

In order to assess the ground water quality for irrigation in the study area, twelve groundwater samples were collected from different productive wells in May, 2019 to cover the entire study area. GPS instrument is used to locate each well site. The borehole depth of the groundwater wells ranged from 60 to 180 m (Table. 1) and (Fig. 2). The groundwater samples were taken after a pumping period of at least 1 h to avoid any local contamination or evaporation. Each sample was collected in acid-washed polyethylene 500 ml bottle and suitable preservatives were added for storage till the completion of quantitative chemical analysis. Each bottle was completely filled with water to avoid air contamination. The bottles were sealed with double plastic caps to prevent evaporation, and precaution was also taken to avoid sample agitation during transfer to the laboratory. The samples were immediately transferred to the laboratory and analyzed.

The collected groundwater samples were analyzed in the environmental laboratory (accredited according to ISO/IE 17025) of Aswan University using Flame Atomic Absorption (Thermo Scientific iCE3000 Series). The methods applied for pH, EC_w and soluble cations and anions are present in Table 2.

Table 1. location, total depth, elevation and designation of the collected groundwater samples:

Sample No.	Well No.	Sample Location		Total depth (m)	Elevation (m.asl)	Designation
		Latitude (N)	Longitude (E)			
1	1	25.068	32.575	120	147	Irrigation
2	2	25.04	32.583	60	146	Irrigation
3	3	25.019	32.64	65	155	Irrigation
4	4	25.042	32.614	75	157	Irrigation
5	5	24.898	32.637	180	141	Irrigation
6	6	24.863	32.658	100	143	Irrigation
7	7	24.721	32.686	130	150	Irrigation
8	8	24.968	32.731	60	137	Irrigation
9	9	24.944	32.79	50	130	Irrigation
10	10	24.924	32.81	60	122	Irrigation
11	11	24.942	32.813	60	120	Irrigation
12	12	24.96	32.797	70	120	Irrigation

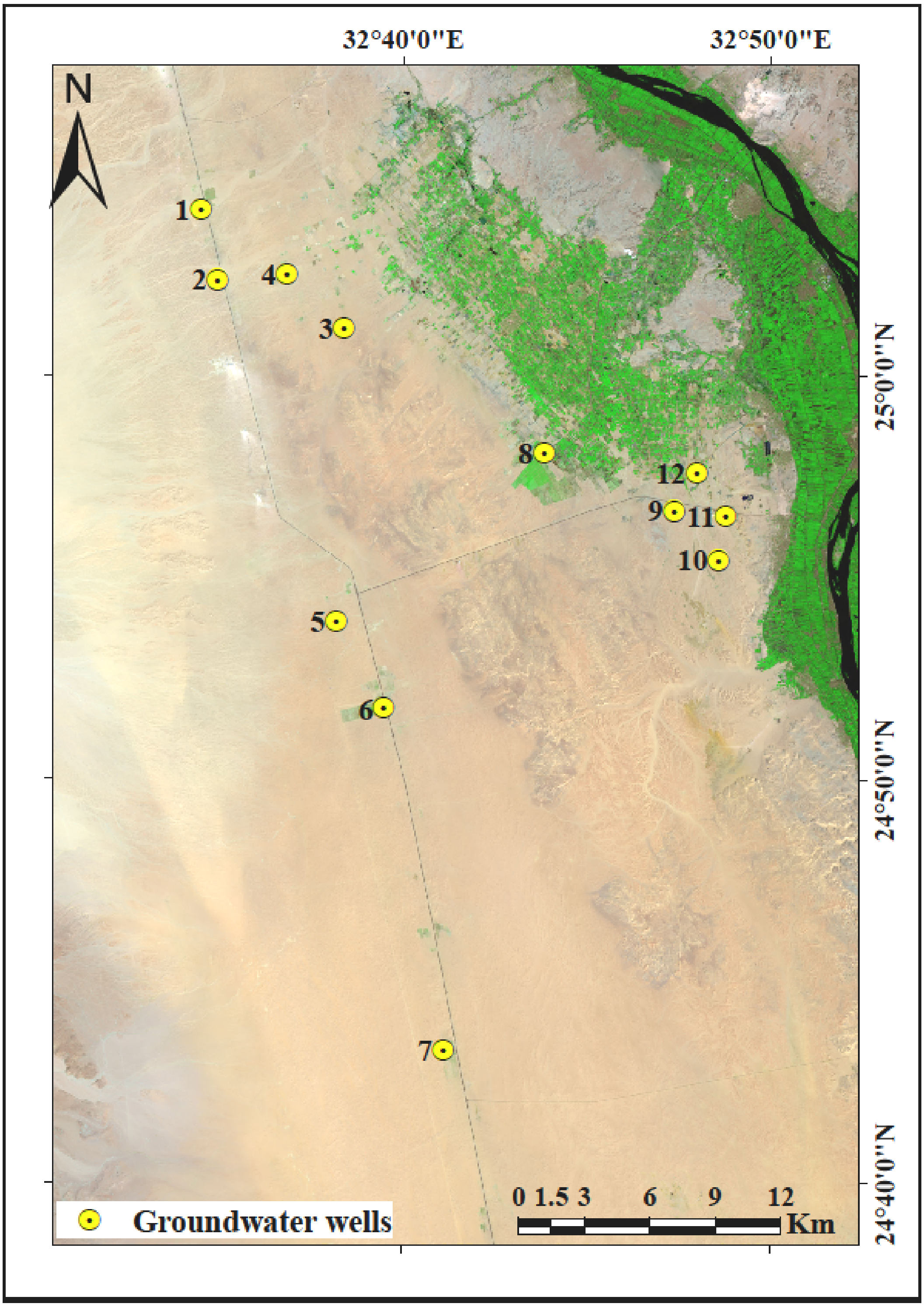

Fig. 2: A location map of the groundwater samples in the studied area.

Table 2. Some chemical methods were used in analyzing the groundwater samples.

Properties	Method applied	Reference
Groundwater-pH	A glass electrode	Mclean, (1982)
Electrical conductivity (EC_w)	The salt bridge method	Rhoades, (1982).
Soluble calcium (Ca^{2+}) and magnesium (Mg^{2+})	The titration with standard versenate (EDTA)	Jackson, (1973)
sodium (Na^+) and potassium (K^+)	The flamephotometery method	Jackson, (1973)
Soluble bicarbonates (HCO_3^-)	The titration with a standard solution of hydrochloric acid.	Jackson, (1973)
Soluble chlorides (Cl^-)	The titration with a standard solution of silver nitrate.	Jackson, (1973)

- The total hardness (TH) in mg/L was determined by the following equation according to Todd, (1980) and Ragunath, (1987):

  $$TH= (2.497xCa) + (4.115xMg) \quad (1)$$

  where the concentrations of Ca and Mg are represented in mg/L.
- The sodium adsorption ratio (SAR) was calculated for each well water by the following equation given by Richards (1954)

  $$SAR=Na/((Ca+Mg)/2)^{½} \quad (2)$$

  where the ions concentration are expressed in meq/L.
- The sodium percentage (%SSP) was estimated using the formula given below (Todd and Mays, 2005):

  $$\%SSP= (Na)\ x100/ (Mg +Ca +Na + k) \quad (3)$$

  where all ions concentration are expressed in meqL.
- The residual sodium carbonates (RSC) was calculated by the following equation (Ragunath, 1987):

  $$RSC= (HCO3 + CO3) - (Mg + Ca) \quad (4)$$

  where all ions concentrations are reported in meq/L.
- The residual sodium bicarbonates (RSBC), as defined by Gupta and Gupta (1987) and were calculated by the following equation.

  $$RSBC= (HCO_3 - Ca) \quad (5)$$

  where ions concentrations are expressed in meq/L.
- The magnesium hazard (MH) for irrigation water is proposed by Szabolcs and Darab (1964) as the following formula:

  $$MH=100x\ [Mg/ (Mg+Ca)] \quad (6)$$

  where all ions concentrations are expressed in meq/L.
- The Kelly's Ratio (KR) was calculated by the following equation (Kelley *et al.*, 1963):

  $$KR= Na/Ca+Mg \quad (7)$$

  where all ions concentrations are expressed in meq/L.
- The permeability index (PI), as defined by Doneen (1964) and Ragunath (1987), is calculated by the following equation:

  $$PI=[([Na^+]+[HCO3^-]^{1/2})]x100/ (Mg^{2+}+Ca^{2+}+Na^++k^+) \quad (8)$$

  where all ions are concentrations expressed in meq/L.
- Iron (Fe), Copper (Cu) and Lead (Pb) were determined by using Flame Atomic Absorption (Thermo Scientific iCE3000 Series).

Results and Discussion:

1. Soluble Cations and Anions

The availability of dissolved ions in the groundwater system is influenced by different geochemical processes that operate in the subsurface hydrogeological system, the relative abundance. Cations concentrations in the groundwater in the study area decreases in the order of $Na^+ > Ca^{2+} > Mg^{2+} > K^+$ while the anions are in the order of $Cl^- > HCO_3^-$ (Table 3). Cation concentrations and anion ratio can trace water- rock interaction processes, such as mineral weathering and cation exchange (Han *et. al,* 2009). Sodium (Na^+) is the dominant cation while potassium (k^+) represents the least dominant one; their concentrations in the groundwater differ from 254.75 to 616.05 mg/L for (Na^{+}) and from 7.61 to 17.34 mg/L for (k^{+}), (Table 3 and Fig.3 – A and B). A low concentration of potassium in the groundwater would originate an alteration form of the silicates which have low solubility rate. Potassium distribution is influenced by the composition of the infiltration rate of the groundwater. Calcium represents the second dominant cation in the majority of the samples. It ranges between 32 and 376 mg/L (Table 3 and Fig.3 – C). Magnesium varies from 33.60 to 196.80 mg/L (Table 3 and Fig.3 – D).

Table 3. Some chemical properties of the analyzed groundwater samples

Sample No.	Well No.	Cations (mg/L)				Anions (mg/L)		EC_w (µs cm^{-1})	TDS (mg/L)	pH
		Na	Ca	Mg	K	Cl	HCO_3			
1	1	353.44	32.00	52.80	11.03	454.40	146.40	1799.00	935.00	7.60
2	2	343.45	40.00	84.00	11.52	461.50	164.70	2155.00	1114.00	7.90
3	3	610.94	270.00	180.00	15.32	1633.00	183.00	7750.00	4020.00	7.10
4	4	616.05	376.00	196.80	17.34	1640.10	158.60	9045.00	4700.00	7.40
5	5	396.14	38.00	67.20	8.53	589.30	122.00	2327.00	1216.00	8.10
6	6	371.89	60.00	84.00	7.61	546.70	164.70	2111.00	1099.00	7.50
7	7	410.02	84.00	45.60	9.32	568.00	195.20	2294.00	1191.00	7.30
8	8	456.61	96.00	76.80	14.19	674.50	305.00	3040.00	1582.00	7.20
9	9	404.23	116.00	70.80	14.80	504.10	134.20	2904.00	1509.00	7.30
10	10	334.91	54.00	33.60	11.93	319.50	140.30	2140.00	1111.00	7.60
11	11	263.45	80.00	50.40	12.69	262.70	207.40	1827.00	950.00	7.40
12	12	254.75	76.00	58.80	13.61	248.50	213.50	1680.00	870.00	7.50

The concentration of Cl^- ions in the groundwater of the study area is between 248.50 to 1640.10 mg/L (Table 3 and Fig.4 - A). The Cl^- is the dominant ion in groundwater suggesting dissolution of the salts. The carbonate rocks (limestone and dolomites are the main source of carbonate and bicarbonate ions in the groundwater. In the study area, the HCO_3^- concentration in groundwater ranges from 122 to 305 mg/L (Table 3 and Fig.4 - B). The value of HCO_3^- ions in groundwater is attributed the dissolution of carbonate rocks by CO_2 in the soil zone.

2. Electric Conductivity (EC_w)

The electrical conductivity (EC_w) of the water samples is an indication of the dissolved ions. Thus, the higher the EC_w values, the higher the level of dissolved ions in the sample. So, it depends on the total concentration of the ionized substances dissolved in the water and the temperature at which the measure-ment is made. The electrical conductivity of all samples ranges from 1680 to 9045 μs/cm (Table 3). The electric conductivity (EC_w) distribution map of the study area is shown in Fig. 5-A. The classification of groundwater on the basis of the U. S. salinity laboratory (1954) shows that 50 % of the groundwater samples falls within the high class (C3) (Table 4) which they cannot be used on soils with restricted drainage moreover 50 % of samples have EC_w values that are higher than 2250 μs/cm (Very High, C4) which they, can be used only on certain crops and then only when special practices are followed.

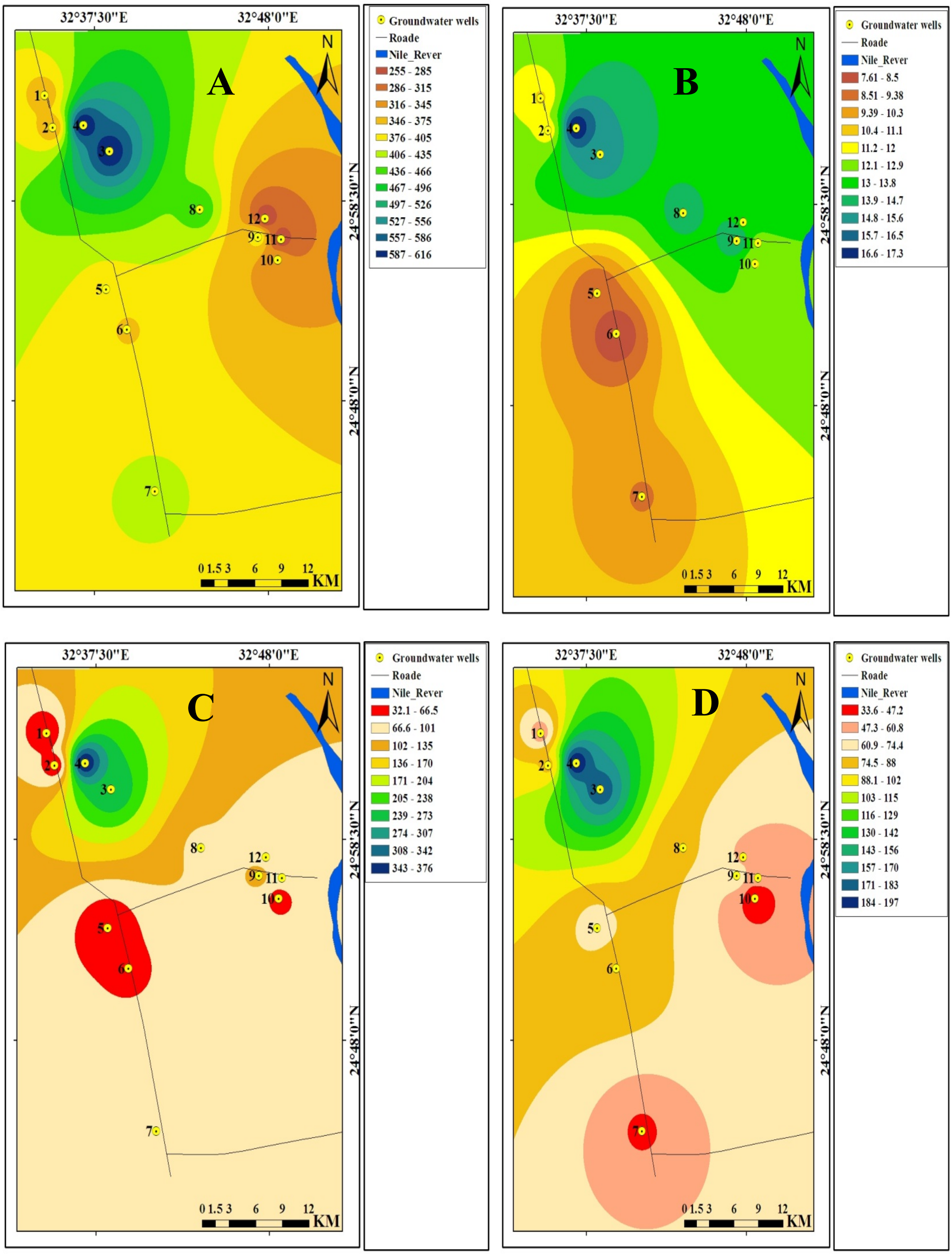

Fig. 3: Distribution maps of Na^+ (A), K^+ (B), Ca^{2+} (C) and Mg^{2+} (D) ions in the studied area

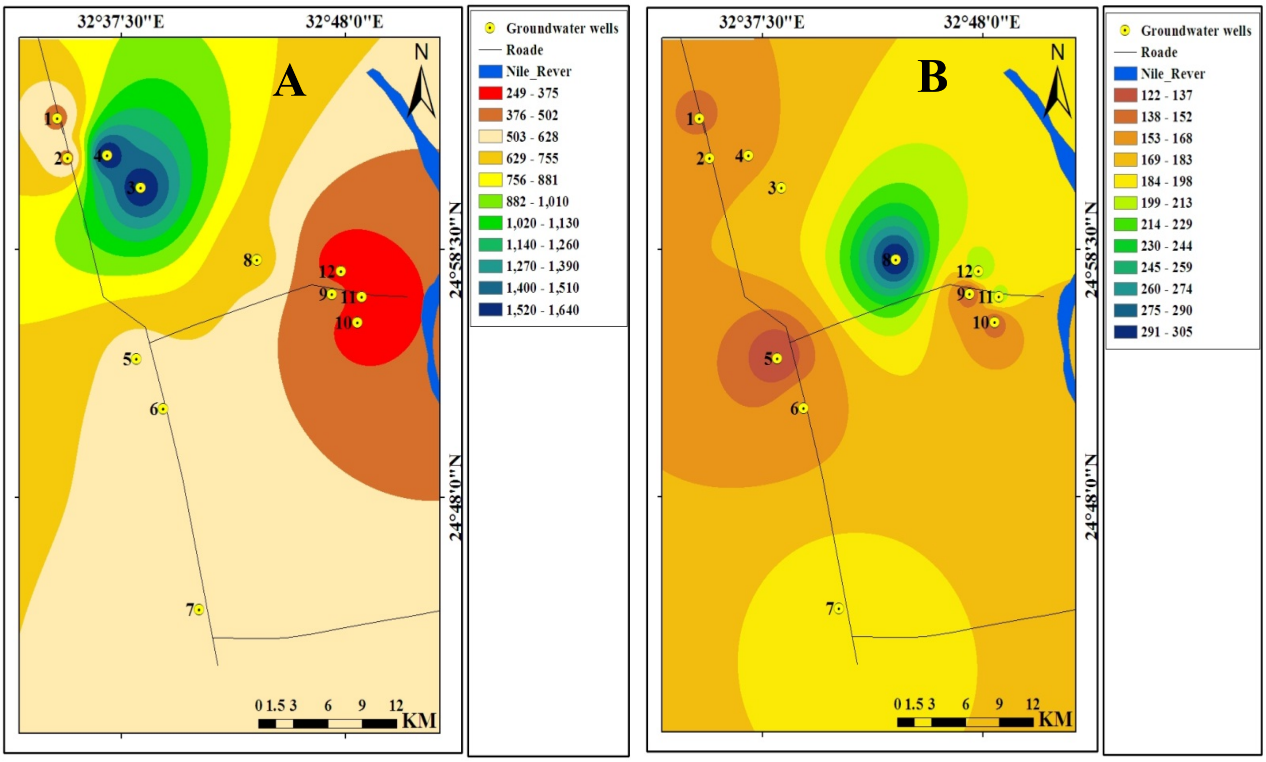

Fig. (4): Distribution maps of Cl^- (A) and HCO_3^-(B) ions of the groundwater samples in the study area.

Table 4. Groundwater EC μs/cm classification according to the U. S. salinity laboratory (1954).

EC_w(μS/cm)	Class No.	Class	% of groundwater Samples	Use of water for irrigation
0-250	C1	Low	Nil	Used for irrigation of most crops on most soils
250-750	C2	Medium	Nil	In a moderate amount of leaching occurs, and crops with moderate salt tolerances, such as potatoes, corn, wheat, and alfalfa.
750-2250	C3	High	50 %	Cannot be used on soils with restricted drainage.
>2250	C4	Very High	50 %	Very poor for irrigation, can be used only on certain crops and then only when special practices are followed.

3. Total Dissolved Salts (TDS)

The total dissolved solid (TDS) is the term used to describe the inorganic salts and small amounts of organic matter present in solution in water. In general, if a ground-water sample has a high TDS level, high concentrations of major constituents will be also present in that sample. The total concentration of Ca^{2+}, Mg^{2+}, Na^+, $(HCO_3)^-$, $(SO_4)^{2-}$, and Cl^- normally comprises more than 90% of the total dissolved solids in the water regardless of whether the water is dilute or it has a salinity greater than seawater (Freeze and Cherry, 1979). The TDS concentrations vary between 870 and 4700 mg/L (Table 3). According to the salinity classification of Hem, (1970), 25 % of the samples are in the range of the fresh water class, 58.33% are in the range of the slightly saline water class, and 16.67% lie in the range of the moderately saline water class (Table 5). The TDS and EC_w distribution maps of the study area (Fig. 5-B) show increasing values toward the south and the north eastern parts of the study area at wells 2, 5, 6, 7, 8, 9 and 10 are slightly saline and wells 3 and 4 are moderately saline, while, the EC_w values decrease in the eastern part of the study area.

Table 5. Classification of the collected groundwater samples according to their contents of total dissolved salts (TDS) (Hem, 1970).

Class No.	Water condition	TDS value in (mg/L)	Well sample	% of groundwater samples
1	Fresh Water	Less than, 1,000	1, 11and12	25
2	Slightly Saline	1,000 to 3,000	2, 5, 6, 7, 8, 9 and 10	58.33
3	Moderately Saline	3,000 to 10,000	3 and 4	16.67
4	Very Saline	10,000 to 35,000	Nil	Nil
5	Brine	More than 35,000	Nil	Nil

4. Hydrogen Ion Concentration (pH)

Generally, water pH is not a problem itself, but it is an indicator of other problems such as sodium and carbonates. The pH balance of a water supply describes how acidic or alkaline is it. The acidity (or alkalinity) of a water supply can affect the plant growth, irrigation equipment, and pesticide efficiency. Alkaline water may contain high concentrations of bicarbonates (generally, in at pH 8 and above) and carbonates (generally, pH 9 and above). So, it can cause calcium and magnesium to precipitate from the soil and it can affect plant growth. Some trace elements, like copper and zinc, will be also less available to plants under this situation. The normal pH range of irrigation water is from 6.5 to 8.4. According to Ayers and Westcot, (1994), the pH of all collected groundwater samples in the study area lies in the acceptable range for irrigation (Table 6 and Fig. 5-C).

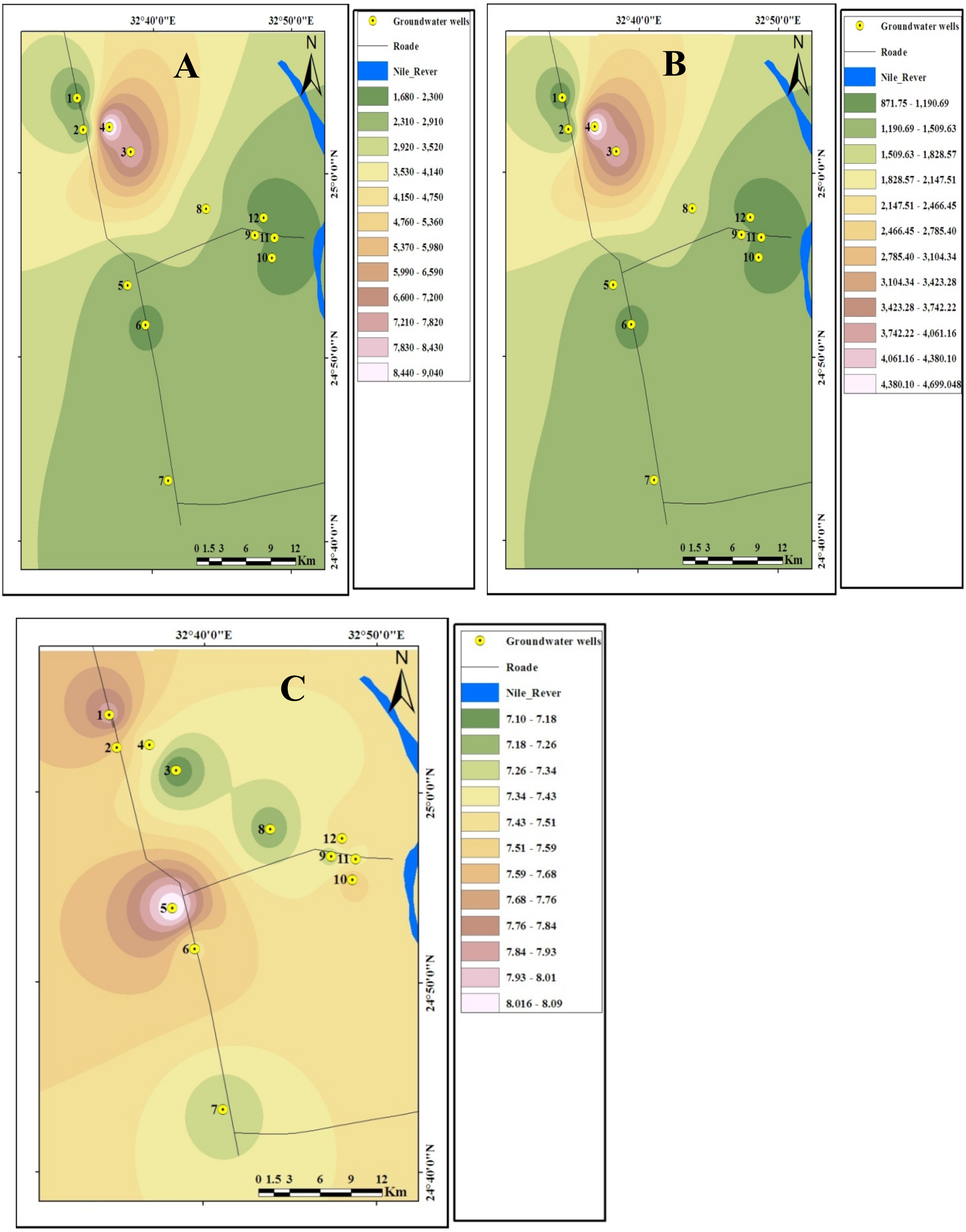

Fig.5: Distribution maps of Electrical Conductivity (EC_W) (A), Total Dissolved Solids (TDS) (B) and groundwater (pH) (C) of the groundwater samples in the study area

Table 6. Groundwater status for irrigation in the study area, according to the guidelines of groundwater pH after Ayers and Westcot, (1994) with groundwater samples.

pH Value	Status for Irrigation Purposes	Well Sample	% of groundwater Samples
> 6.5	Not Acceptable	Nil	Nil
6.5 - 8.5	Acceptable	All groundwater samples	100
< 8.5	Not Acceptable	Nil	Nil

5. Total Hardness (TH)

Ragunath, (1987) classified the water into various degrees of hardness as shown in The TH values which tabulated with their corresponding classes in Table 7 are used to construct the total hardness contour map of the study area. The TH-values of the groundwater samples in the study area range between 273.10 and 1748.70 mg/L (Table 8). According to Ragunath's classification (Table 7), the groundwater samples of the study area classified as 66.67 % are very hard water and 33.33 % of them are excessively hard water. The distribution map of the total hardness (Fig. 6-A) shows an increase in the north eastern part of the area which is related to the high concentration of Ca^{2+} and Mg^{2+} ions in this part, while the TH values decrease toward the south and middle parts of the study area.

Table 7. Classification of water in the study area according to degrees of hardness (Ragunath, 1987)

Hardness range (mg/L)	Water type	Well sample	% of groundwater Samples
00 – 55	Soft water	Nil	Nil
56 – 100	Slightly hard water	Nil	Nil
101 – 200	Moderately hard water	Nil	Nil
201 – 500	Very hard water	1,2,5,6,7,10,11 and 12	66.67
more than 500	Excessively hard water	3,4,8 and 9	33.33

Table 8. Some parameters of the groundwater samples in the study area used to assess the qualityof irrigation water.

Sample	Well	(mg/L)	(meq/L)			(%)			--
No.	**No.**	**TH**	**SAR**	**RSC**	**RSCB**	**MH**	**SSP**	**PI**	**KI**
1	**1**	317.15	8.87	-3.60	0.80	73.33	70.98	78.14	2.56
2	**2**	425.56	7.04	-6.30	0.70	77.78	61.63	68.42	1.66
3	**3**	1414.89	7.04	-25.50	-10.50	52.63	47.90	51.02	0.93
4	**4**	1748.70	6.38	-32.60	-16.20	46.59	42.90	45.49	0.76
5	**5**	371.41	8.89	-5.50	0.10	74.67	69.05	74.72	2.30
6	**6**	495.48	7.23	-7.30	-0.30	70.00	61.33	67.56	1.62
7	**7**	397.39	8.91	-4.80	-1.00	47.50	68.39	75.25	2.23
8	**8**	555.74	8.39	-6.20	0.20	57.14	63.19	70.31	1.77
9	**9**	580.99	7.27	-9.50	-3.60	50.43	59.27	64.27	1.50
10	**10**	273.10	8.78	-3.20	-0.40	50.91	71.49	78.94	2.65
11	**11**	407.16	5.66	-4.80	-0.60	51.22	57.33	66.56	1.40
12	**12**	431.73	5.31	-5.20	-0.30	56.32	55.04	64.33	1.27

6. Sodium Adsorption Ratio (SAR)

According to the U.S. Salinity Laboratory, (1954), the sodium-adsorption ratio (SAR) is used to express the relative activity of sodium ions in exchange reactions with the soil, which it is better measure of the suitability of water for irrigation. The water is classified for the SAR into four main classes as indicated in Table (9). The SAR values range from 5.31 to 8.91 meq/L (Table 8 and Fig. 6-B) and according to the U.S. Salinity Laboratory, (1954) all groundwater collected samples belong to the low class, which it can be us to irrigate all types of soils.

Table 9. Groundwater SAR classification according to the U. S. Salinity laboratory (1954).

SAR	Class No.	Class	% of groundwater Samples	Use of water for irrigation
0-10	S1	Low	100	In all types of soil
10-18	S2	Medium	Nil	In coarse textural soils with high permeability and rich in organic matter.
18-26	S3	High	Nil	Requires good drainage and chemical amendments.
>26	S4	Very High	Nil	Very poor for irrigation, require low salinity water, good drainage and addition of gypsum.

7. Residual Sodium Carbonate (RSC)

The residual sodium carbonate (RSC) value refers to the bicarbonate content of the water. A high concentration of bicarbonate in water leads to increase the pH value of this water. An increase in the RSC value in the water leads also to precipitate calcium and magnesium that can cause an increase in sodium content in the soil irrigated with this water. The high bicarbonate ion concentration in irrigation water causes plant toxicity and affects the mineral nutrition of plants. The classification of water quality for irrigation based on the RSC was proposed by Eaton, (1950). Based on this classification, all the groundwater samples collected from the study area fall in the good class which the RSC ranges from -32.60 to -3.20 meq/L (Tables 7 and 10) and Fig. 6-C).

Table 10. Residual Sodium Carbonate (RSC) classification of the groundwater samples in the study area according to Eaton, (1950).

RSC (meq/L)	Class	% of groundwater samples
< 1.25	Good	100
1.25 - 2.5	Doubtful	Nil
> 2.5	Unsuitable	Nil

8. Residual Sodium Bicarbonate (RSCB)

Gupta and Gupta (1987) defined RSBC as RSBC = (HCO_3^- - Ca^{2+}) (All ions are in equivalent per liter). According to Gupta and Gupta (1987) waters are satisfactory for agricultural practice if the RSBC < 5 meq/L. It was observed that the RSBC of the groundwater samples in the study area varies between -16.20 to 0.8

meq/L, which are within the satisfactory level (Table8 and Fig. 6-D).

9. Magnesium Hazard (MH)

Szabolcs and Darab (1964) proposed a magnesium hazard (MH) parameter to assess irrigation water. A magnesium ratio of groundwater of more than 50 is considered to be harmful and unsuitable for irrigation use. This would adversely affect the crop yield, as soils become more alkaline. The magnesium ratio values of the study area range from 46.59 to 77.78 (Table 8). The majority of groundwater samples (83.33%) have a magnesium hazard ratio above 50 which are considered as harmful and unsuitable for irrigation use but 16.67% of groundwater samples have a MH ratio less than 50 % which suitable for irrigation (Table 12 and Fig. 7-A).

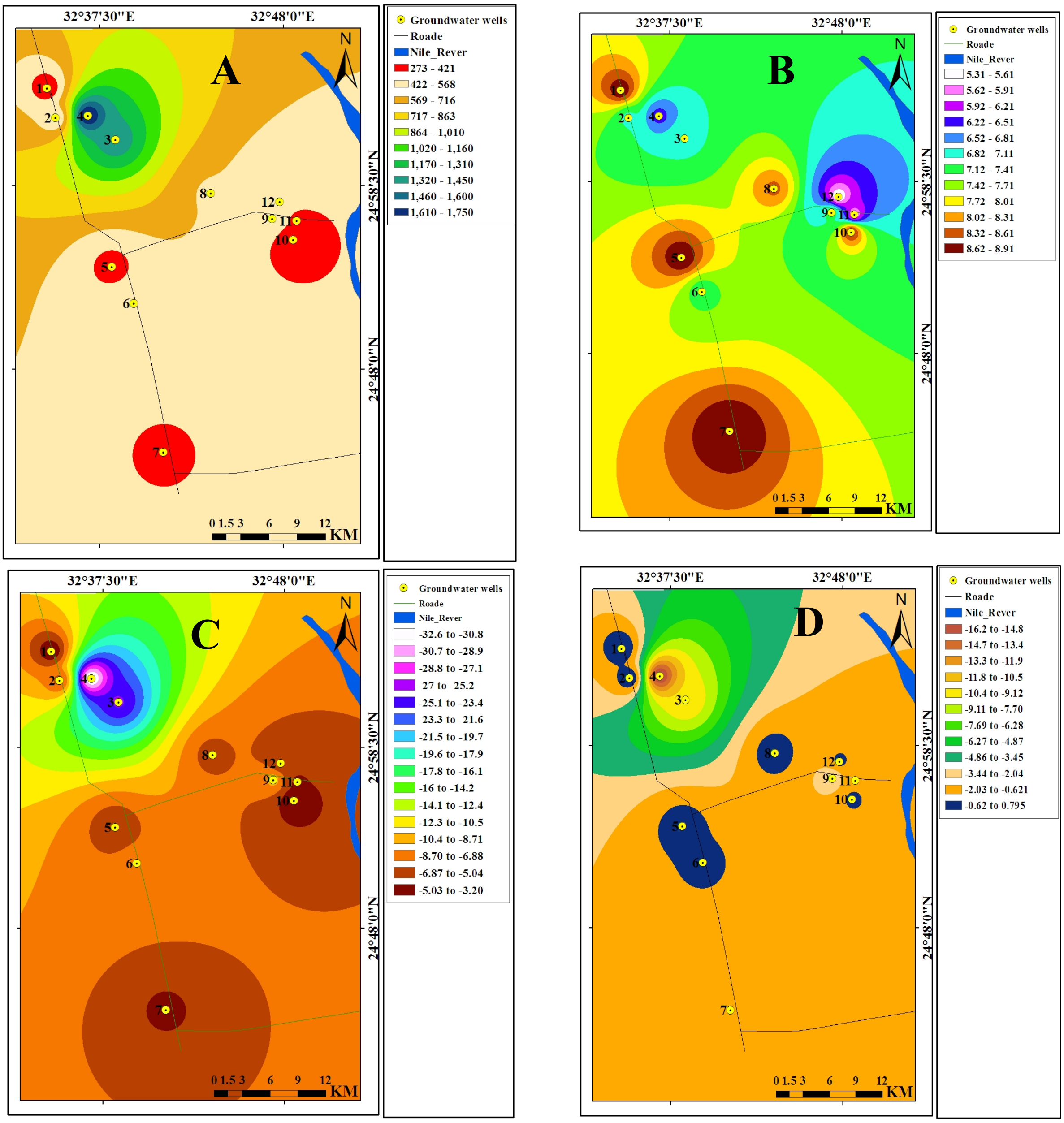

Fig.6: Maps showing the distribution of total hardness (TH) (A), sodium adsorption ratio (SAR) (B), residual sodium carbonate (RSC) (C) and residual sodium bicarbonate (RSCB) (D) of the groundwater samples in the study area.

Table 11. Magnesium hazard classification of the groundwater samples in the study area according to Szabolcs and Darab (1964)

Water type	Magnesium hazard (%)	Well sample	% of groundwater Samples
Suitable for Irrigation	< 50	4 and 7	16.67
Unsuitable for Irrigation	> 50	1,2,3,5,6,8,9,10,11and12	83.33

10. Soluble Sodium Percentage (SSP)

Wilcox (1955) used the sodium percentage and specific conductance in the groundwater in evaluating its suitability for irrigation. Sodium percentage determines the ratio of sodium concentration to the concentration of the total cations (sodium, potassium, calcium and magnesium). All concentration values are expressed in equivalents per liter. The (SSP) values range from 42.90 to 71.49 % (Table 8) and (Fig. 7-B). The SSP classification of the groundwater samples in the study area according to Wilcox (1955) is shown in (Table 12). It is observed that about 41.67 % of the samples are permissible and 58.33 % of these water samples are Doubtful.

Table 12. Soluble sodium percentage (SSP) classification of the groundwater samples in the study area according to Wilcox (1955).

SSP of water (%)	Water type	Well sample	% of groundwater Samples
0-20	Excellent	Nil	Nil
20-40	Good	Nil	Nil
40-60	Permissible	3,4,9,11 and12	41.67
60-80	Doubtful	1,2,5,6,7,8 and10	58.33
>80	Unsafe	Nil	Nil

11. Permeability Index (PI)

The permeability of the soil is affected by the long-term use of irrigation water as it is influenced by Na^+, Ca^{2+}, Mg^{2+} and HCO_3^-, contents of the soil (Ramesh and Elango, 2012). The WHO (2011) uses a criterion for assessing the suitability of water for irrigation based on the permeability index (PI), where the required ion concentrations are in meq/L (Ragunath, 1987). The PI values of the groundwater samples in the study area range from 45.49 to 78.94 % (Table 8 and Fig. 7-C). The water of wells 2, 3, 4, 5, 6, 8, 9, 11 and 12 that have a PI value between 25 to 75% that represent class 2 are good for irrigation. Wells 7 and 10 represented by PI >75% indicating that the groundwater are excellent for irrigation (Table 13).

Table 13. Permeability index (PI) classification of the groundwater samples in the study area according to (Ragunath, 1987).

Permeability Index (PI %)	Water type	Well sample	% of groundwater Samples
< 25	Unsuitable	Nil	Nil
25-75	Good	1,2,3,4,5,6,7,9 and 10	75
>75	Excellent	8,11 and 12	25

12. Kelley's Index (KI)

Kelley *et al.* (1963) suggested that the sodium problem in the irrigational water could very conveniently be worked out on the basis of the values of Kelley's ratio. Groundwater having a Kelley's ratio more than one is generally considered as unfit for irrigation. The Kelley's ratio of the groundwater samples in the study area varies from 0.76 to 2.65 (Table 8). The result show that 16.67 % of the samples (wells 1 and 2) are less than one, reflecting their suitable for the irrigation purposes. On the other hand, 83.33 % of the samples (wells 3 to 12) have ratios greater than one which they are unsuitable. (Table 14 and Fig. 7-D).

Table 14. Kelley's Index (KI) classification of the groundwater samples in the study area according to Kelley *et al.*, (1963).

Kelley's Index (KI)	Water type	Well sample	% of groundwater samples
< 1	Suitable	3 and 4	16.67
>1	Unsuitable	1,2,5,6,7,8,9,10,11 and 12	83.33

13. Some Trace Elements and Heavy Metals

Some heavy metals are of great concern because of their toxic effects even at low concentrations. Table 15 shows the concentrations of some trace and heavy ions (mg/L) in the groundwater samples of the study area. These metals are Iron (Fe), Copper (Cu) and Lead (Pb).

13.1. Iron (Fe):

Iron in ground water may originate from a variety of mineral sources; and several sources of iron may be present in a single aquifer system. The concentration of iron in the groundwater samples of the study area is it varies from 0.077 to 0.512 mg/L (Table 15). The distribution of iron Fig.8-A shows a general increase in the western part of the study area, and decreasing to the north side. According to the FAO. (1985), the concentrations of iron in all samples are below the toxicity limit that is less than 5 mg/L.

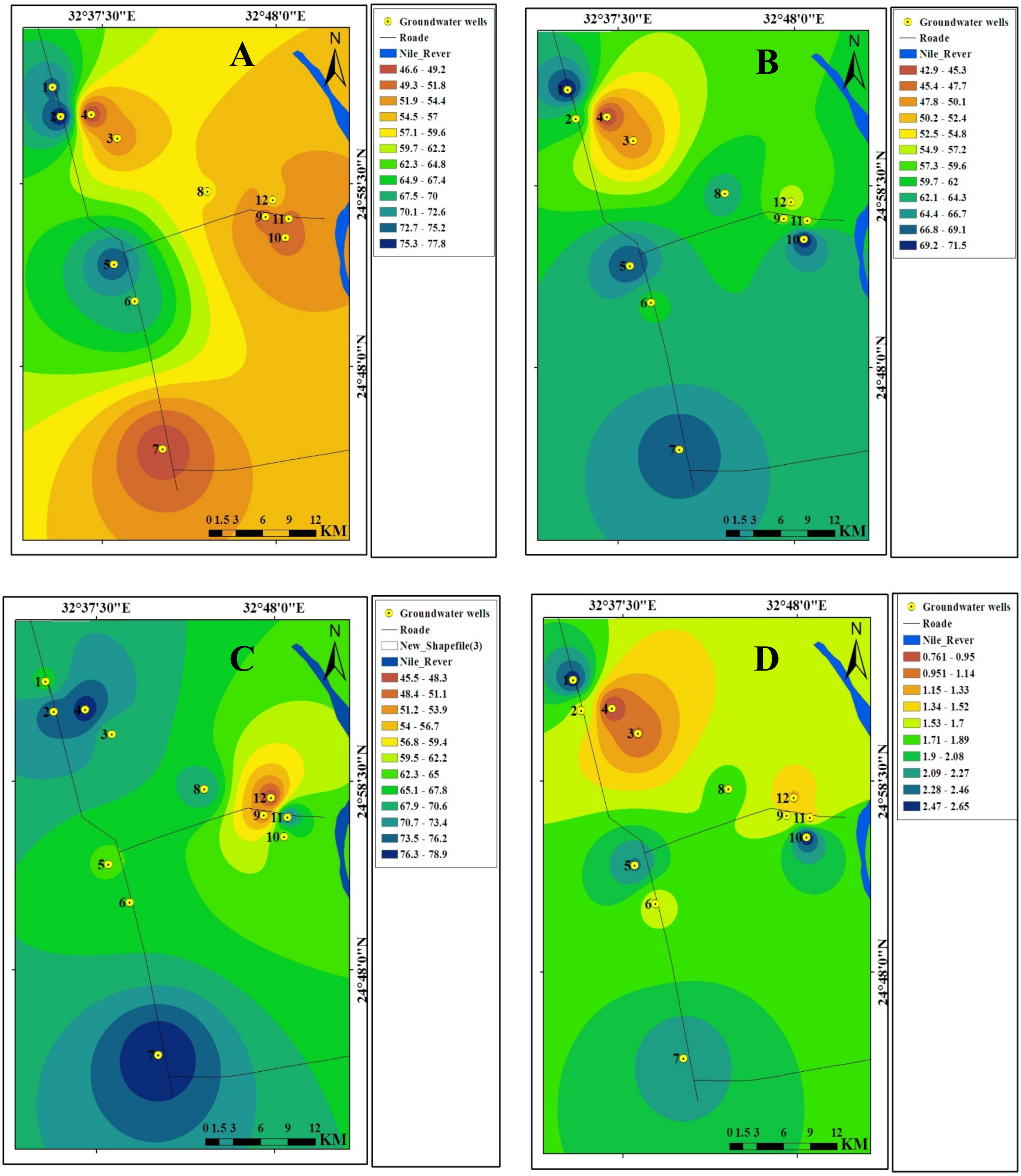

Fig.7: Distribution maps of magnesium hazard (MH**)** (A), soluble sodium percentage (SSP) (B), Permeability Index (PI) (C) and Kelley's Index (KI) (D) of the groundwater samples in the study area.

Table 15. Some trace and heavy metals of the groundwater samples in the study area.

Sample No.	Well No.	mg/L		
		Fe	Cu	Pb
1	1	0.151	Not Det.	0.048
2	2	0.077	Not Det.	0.035
3	3	0.113	0.003	0.043
4	4	0.151	0.008	0.05
5	5	0.146	0.011	0.062
6	6	0.155	0.01	0.564
7	7	0.397	0.016	0.062
8	8	0.23	0.017	0.056
9	9	0.237	0.018	0.057
10	10	0.32	0.02	0.054
11	11	0.427	0.018	0.062
12	12	0.512	0.018	0.062

13.2. Copper (Cu)

Copper concentration in surface waters reaches 7 μg/L, in ground water is about 3 μg/L and in sea water ranges between 0.5 to 12 μg/L (Crompton, 1997). Concentrations of copper in drinking water do not exceed 1.5 mg/L according to WHO, 1971. In the study area Cu concentrations is under the permissible limit (less than 0.2 mg/L) which could be used for using for irrigation according to (FAO. 1985), that it varies from 0.003 to 0.02 mg/L (Table 15 and Fig.8-B).

13.3. Lead (Pb)

Lead is one of the naturally limited occurrence elements. It occurs as a sulfide in rocks and replaces K, Ba, Sr and Ca in minerals (Norrish, 1975). Lead is a non-essential element for plants. In fresh water, it is very low, but when a high concentration is recorded, it may result from industrial pollutions. The average lead concentration in the sea water is 0.3 mg/L, in natural unpolluted river is equal to 3 μg/L (Al-Manharawi and Hafiz, 1997), and does not exceeds 3 μg/L in groundwater (Langmuir, 1997). The concentration of lead in the collected groundwater samples varies between 0.035 to 0.564 mg/L (Table 15 and Fig.8-C). According to FAO, (1985), all groundwater samples are falling below the toxicity limit (less than 5 mg/L).

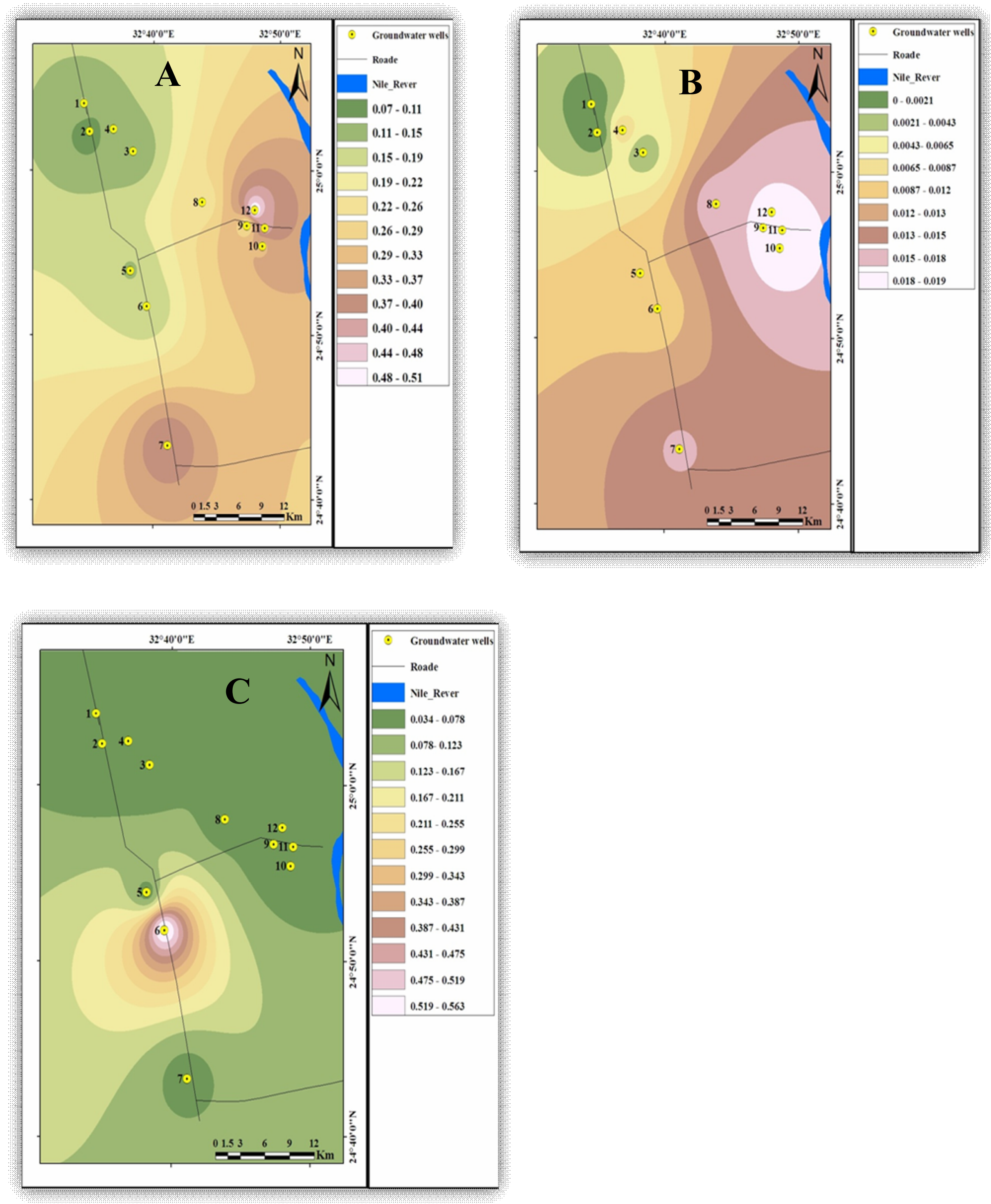

Fig.8: Distribution maps of iron (A), Copper (B) and Lead (C) of the groundwater samples in the study area.

Conclusions

Quality assessment shows that, in general, the groundwaters in west Edfu are suitable for irrigation purposes. However, the TH, KI, MH and SSP values of most water samples, make them unsuitable for irrigation. The soluble sodium percentage (SSP) of the groundwater samples differs between permissible and doubtful. The total hardness (TH) values of these samples in the study area are classified as very hard to excessively hard water according to Ragunath, (1987). Most of magnesium hazard (MH) values of groundwater in the area under study are unsuitable for irrigation according to Szabolcs and Darab (1964). Also most of these groundwater samples in the area under investigation have Kelley's ratio that is unsuitable for irrigation. According to their SAR, RSC, RSCB and PI values, the investigated groundwater samples are suitable for irrigation. Moreover, all these samples of show pH values those are under the acceptable range for irrigation, (Ayers and Westcot, 1994). According to the U. Salinity laboratory (1954), the electrical conductivity of the groundwater varies from high to very high saline. However, the total dissolved solids (TDS) vary between fresh water, slightly saline and moderately saline waters (Hem, 1970). The distribution maps of the major ions (Ca, Mg, Na, K, Cl, and HCO_3) in this groundwater samples are nearly compatible. Which, their highest concentrations is observed in the northern part of the study area However, the concentrations of Fe, Cu and Pb are high in the middle part of the study area. Both Cu and Pb levels in the groundwater samples are less than the standard limit (>5 mg/L) of FAO, 1985 and are suitable for irrigation. The iron in all groundwater samples is less than the standard limit (>5 mg/L) of FAO, (1985) which are suitable for irrigation.

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Assiut J. Agric. Sci., 51 (1) 2020(125-149) *ISSN: 1110-0486*
Website: *www.aun.edu.eg/faculty_agriculture/journals_issues_form.php* ***E-mail: ajas@aun.edu.eg***

تقييم جودة المياه الجوفية للري فى منطقة غرب إدفو، أسوان، مصر

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الملخص:

تقع منطقة غرب إدفو ضمن حوض الجلابة الذي يعتبر جزءًا مهمًا من مشروع الاستصلاح القومى المصري الذي تبلغ مساحته ١,٥ مليون فدان والتى جذبت المستثمرين لاستصلاح وتطوير مستوطنات جديدة. المياه الجوفية هي مصدر المياه الوحيد لهذا التطوير المتكامل وبالتالى نقوم بتقييم جودة هذه المياه لأغراض الرى حيث تم جمع اثني عشر عينة من مياه الأبار الجوفية التى تقع غرب إدفو والتى تقع فى الصحراء الغربيه و تقع منطقة الدراسة بين دائرتى عرض ٢٤° ٤٠' ٠٠" و ٢٥° ٧' ٢٢" شمالا وخطى طول ٣٢° ٣٢' ٥٢" و ٣٢° ٥٠' ٠٠" شرقا. تم تحديد الخواص الكيميائية للمياه الجوفية في الأبار قيد الدراسة التي تم فحصها مثل التوصيل الكهربى (EC_w)، إجمالى المواد الصلبة الذائبة (TDS)، رقم الأس الهيدروجيني pH ، الصوديوم، البوتاسيوم، الكالسيوم، الماغنسيوم، الكلوريد، البيكربونات، الحديد، الرصاص والنحاس بالأضافة إلى مؤشرات الري مثل العسر الكلى (TH)، نسبة إدمصاص الصوديوم (SAR)، كربونات الصوديوم المتبقية (RSC)، نسبة الصوديوم الذائب (SSP)، ضرر المغنيسيوم (MH)، بيكربونات الصوديوم المتبقية (RSCB)، مؤشر النفاذية (PI) ومؤشر كيلي (KI). وفقًا لـ Ayers and Westcot, (1994) فإن جميع عينات المياه الجوفية فى منطقة الدراسة كانت ذات رقم pH ملائم للري كما تناقص تركيز الكاتيونات في هذه المياه الجوفية على النحو الصوديوم > الكالسيوم > الماغنسيوم > البوتاسيوم أما تركيز الانيونات فقد تناقص فى إتجاه الكلوريد > البيكربونات وقد تراوحت قيم EC_w و TDS فى هذه العينات من ١٦٨٠ إلى ٩٠٤٥ ميكروموز / سم و ٨٧٠ إلى ٤٧٠٠ ملجم / لتر على التوالي أما قيم نسبة إدمصاص الصوديوم و كربونات الصوديوم المتبقية وبيكربونات الصوديوم المتبقية فقد تراوحت من ٥,٣١ إلى ٨,٩١ & -٣٢,٦٠ إلى -٣,٢٠ و ١٦,٢٠ إلى ١,١٠ مللي مكافئ / لتر على التوالي وأختلفت قيم مؤشر النفاذية (PI)، مؤشر كيلي (KI)، نسبة الصوديوم الذائب (SSP) و ضرر المغنيسيوم (MH) من ٤٢,٩٠ إلى ٧١,٤٩ ٪، ٠,٧٦ إلى ٢,٦٥ ، ٤٦,٥٩ إلى ٧٧,٧٨ ٪ ومن ٤٥,٤٩ إلى ٧٨,٩٤٪ على التوالي أما توزيع الحديد والنحاس في المياه الجوفية فكان مرتفعا في الجزء الشرقي من منطقة الدراسة، بينما تركيز الرصاص كان مرتفعا في الجزء الأوسط من منطقة الدراسة.