Hydrochemistry for Umm Er Radhuma Aquifer – West of Iraq

Ahmed Nadhim Al-Fatlawi
The General Commission for Groundwater

Qusai Y. Al-Kubaisi
University of Baghdad

Abstract:

Chemical analysis of groundwater samples taken from old and new wells, there were (30) new wells sampled in the studied area besides the information of 60 old wells (data bank wells- Ministry of Water Resources), showed that the groundwater was not suitable for drinking and industry but it is suitable for animal watering, building and most types of summer and winter crops because the salinity of the water is within the permissible limits when considering the nature of the soil. The best water quality in Umm Er Radhuma aquifer is found in the recharge zone at the western edge of the aquifer where it is recharged by Wadi Horan. The groundwater TDS value ranges between (1000 – 2000) ppm, increasing with the flow direction toward the east and the northeast until it attains a value of about 5000 ppm in the discharge zone in the east part of Umm Er Radhuma aquifer.

الخلاصة:

أخذت نتائج التحليل الكيميائي لعينات المياه الجوفية من الآبار القديمة والجديدة. هنالك (30) بئر جديد اختيرت في المنطقة المدروسة إضافةً إلى معلومات (60) بئرِ قديمِ (بنك معلومات الآبار – وزارة الموارد المائية). المياه الجوفية وجدت غير صالحة لشرب الإنسان والصناعة لكنها مناسبةَ لإرواء الحيوانات والبناء وتستخدم للري لمختلف أنواعِ المحاصيلِ الصيفية والشتوية لأن ملوحةَ الماء ضمن الحدود المسموح بها عند الأخذ بنظر الاعتبار طبيعة التربة. أفضل نوعية مياه في مكمن أم أرضمة يوجد في مناطق التغذية عند الحافة الغربية للمكمن حيث يتغذى مكمن أم أرضمة من وادي حوران. تتراوح قيمة الأملاح الصلبة المذابة بين (1000-2000)ملغم/لتر وتزداد هذه النسبة باتجاه الجريان نحو الشرقِ والمنطقة الشمالية الشرقية حتى تصل إلى حوالي(5000) ملغم/لتر في نطاق التصريف في الجزء الشرقي لمكمن أم أرضمة.

Introduction:

The studied area is located between the Euphrates river and the Saudi Arabian borders, it forms about (151,834) km^2 of the Iraqi Western Desert covering Umm Er Radhuma geological formation inside Iraq, (Figure 1).

مستل من أطروحة دكتوراه للباحث الأول

ISSN 2072-3875

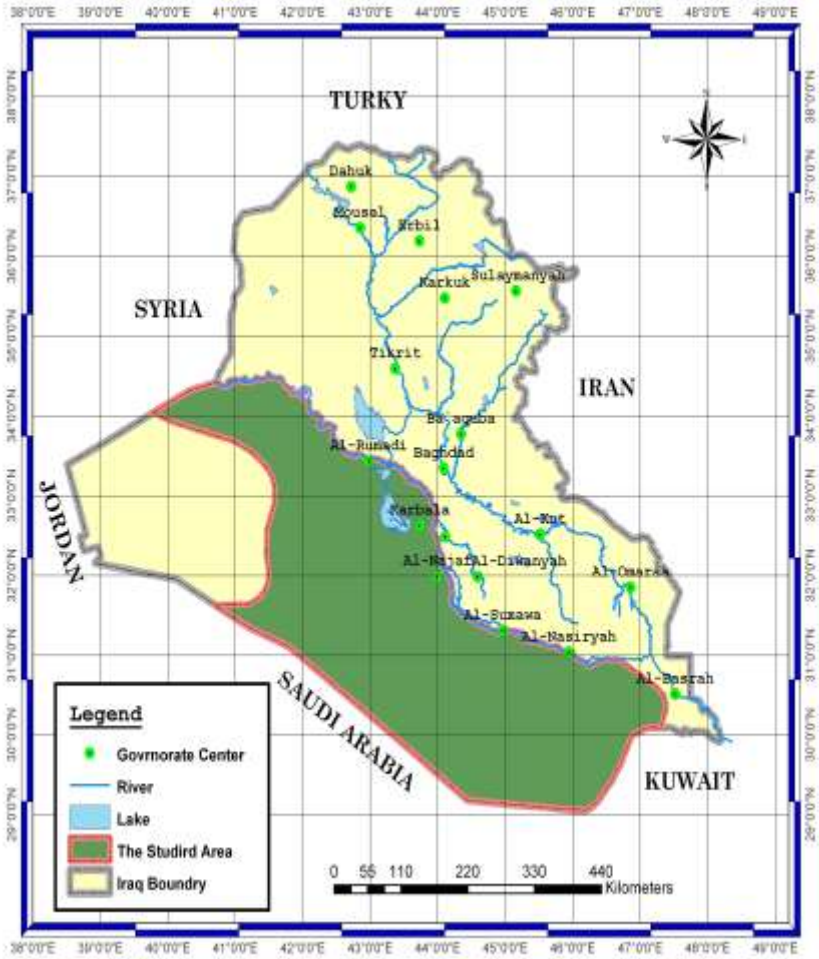

Figure (1) Location map

The quality of groundwater is of nearly equal importance to quantity. The quality required of groundwater supply depends upon its purpose, thus, the needs for drinking water, industrial water, and irrigation water vary widely (Todd, 1980). The study of groundwater quality involves a description of the occurrence of its various constituents and the relation between these constituents to the materials which exist in the aquifer. The data on groundwater quality give important clues to the geological history of the rocks and indications of groundwater recharges, discharges, movement, and storage (Walton,1970). There are (30) new wells sampled in the studied area and besides the information of 60 old wells (data bank wells) as shown in Figures (2), (3).

ISSN 2072-3875

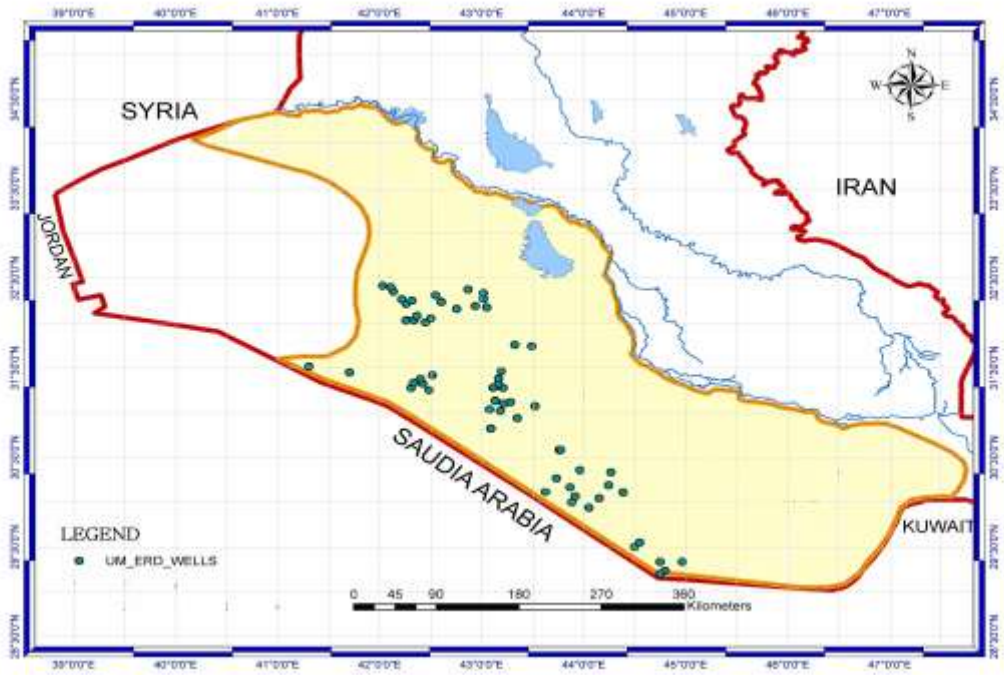

Figure (2) Locations of the water samples of the old wells in the studied area

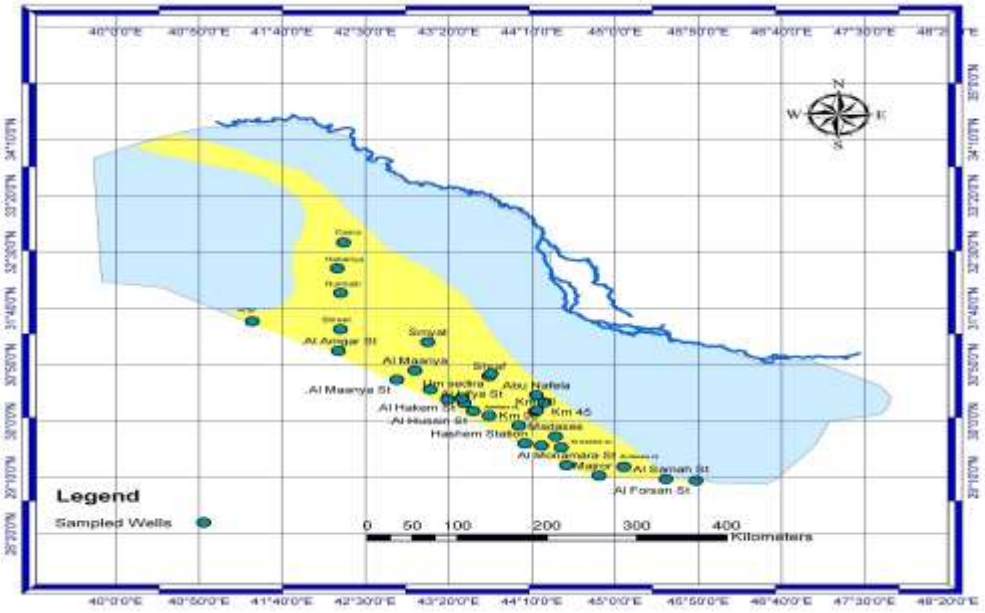

Figure (3) Locations of the water samples of the new wells in the studied area

Physical analysis of water samples:

-Electrical Conductivity (EC):

The (EC) values of water samples were as in table (1).

ISSN 2072-3875

Table (1) The (EC) values of water samples for the old and new wells

EC(µs/cm)	Old wells	New wells	
		Dry period(October)	Wet period (April)
Range	1425 - 5370	7790 -1445	1235 - 7280
Average	2818.98	3058.2	2783.8
The most repeated	2000 - 3000	3000 - 4000	

The (EC) values of the wet period are slightly lower than the dry period due to dilution process by rainfall.

When comparing EC values , Table (1), with those of Table (2) it could be concluded that the type of groundwater in the studied area is excessively mineralized. Figures (4),(5) show the distribution of EC in the studied area.

Table (2) Relationship between electrical conductivity and water mineralization (Detay, 1997).

EC (µc / cm)	Mineralization
<100	Very Weakly Mineralized water
100-200	Weakly Mineralized water
200-400	Slightly Mineralized water
400-600	Moderately Mineralized water
600-1000	Highly Mineralized water
>1000	Excessively Mineralized water

-Dissolved Solids (TDS):

According to, Altoviski, 1962; Drever, 1997; and Todd, 2007, the classification of water on the basis of the (TDS) is shown in Table (3):

ISSN 2072-3875

Table (3) Classification of water salinity according to (TDS) in (ppm).

Altoviski(1962)	Drever(1997)	Todd(2007)	Water Class
0-1000	<1000	10-1000	Fresh Water
1000-3000	1000-2000	-----	Slightly brackish Water
3000-10000	2000-20000	1000-10000	brackish Water
10000-100000	------	10000-100000	Salty Water
----------	35000	----	Saline Water
>100000	>35000	>100000	Brine Water

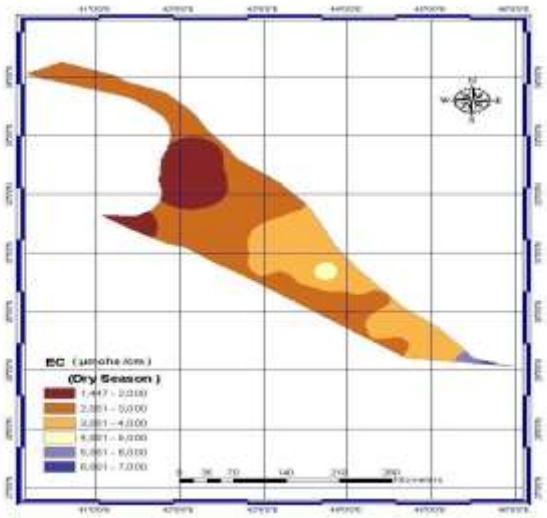

Figure (4) shows the distribution of EC in the unconfined aquifer during the dry period

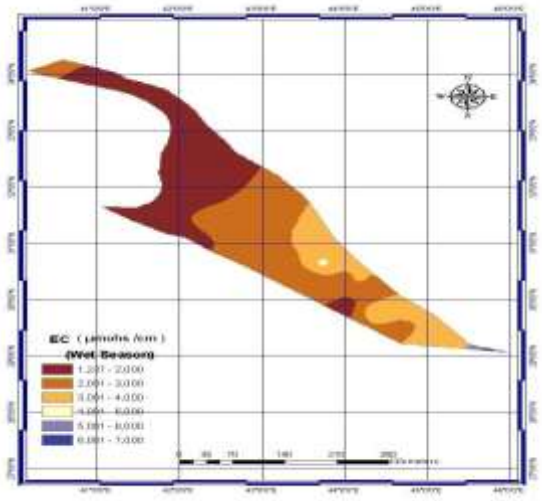

Figure (5) shows the distribution of EC in the unconfined aquifer during the wet period

ISSN 2072-3875

The (TDS) values of water samples were as in Table (4).

Table (4) The (TDS) values of water samples for the old and new wells

TDS (ppm)	Old wells	New wells	
		Dry period(October)	Wet period (April)
Range	1028-4401	6000 - 1090	1050 - 5870
Average	2282.2	2161.17	2002
The most repeated	2000 - 3000	2000-3000	

When comparing the values of (TDS) ,Table (4) for wells within the classifications, Table (3), we notice that all water samples are considered to be slightly brackish water. Figures (6) and (7), show the distribution of TDS in the studied area.

Salinity increases to the east as well as the south eastern part of the studied area due to the dissolving as a result to the movement of the water towards the discharge area. Salinity decreases through the wet period, because the dilution of water by rainfall.

- pH:

The pH values of water samples were as in Table (5).

Table (5) The (pH) values of water samples for the old and new wells

pH	Old wells	New wells
Range	6.9-8.2	7.08-8.8
Average	7.78	7.7

Chemical analysis of water samples:

- Major Cations :

1- Sodium Ion (Na^+):

The sodium ion (Na^+) concentration of water samples is shown in Table (6),

Table (6) The (Na^+) concentration in water samples for the old and new wells

Na^+ (ppm)	Old wells	New wells	
		Dry period(October)	Wet period (April)
Range	48-529	1000 - 72	42 - 948
Average	166.3	347.97	299.87
The most repeated	100-200	200-300	

ISSN 2072-3875

The decrease of Na concentrations in wet period is due to the dilution process by rainfall.

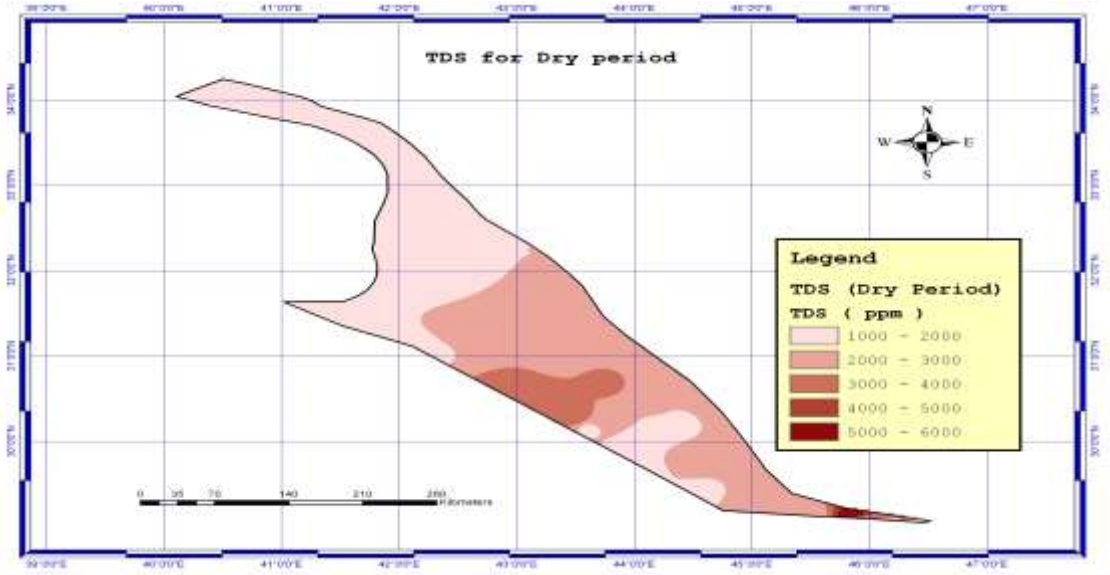

Figure (6) the distribution of TDS in the unconfined aquifer during the dry period

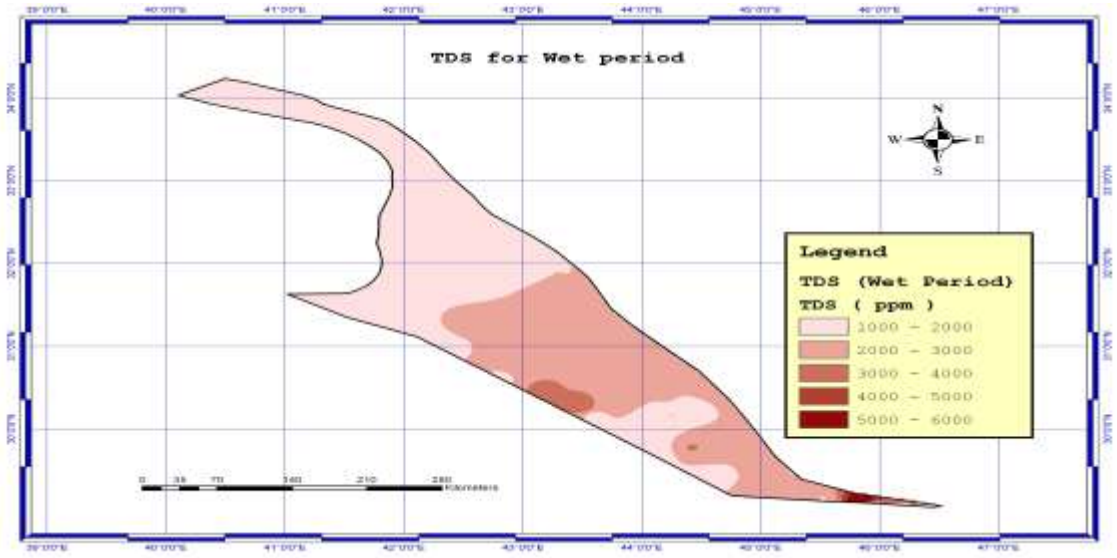

Figure (7) The distribution of TDS in the unconfined aquifer during the wet period

2- Calcium Ion (Ca^{+2}):

The calcium ion (Ca^{+2}) concentration in water samples is shown in Table (7).

ISSN 2072-3875

Table (7) The (Ca^{+2}) concentration of water samples for the old and new wells

Ca^{+2} (ppm)	Old wells	New wells	
		Dry period(October)	Wet period (April)
Range	92-656	389 - 38	34 - 375
Average	349.37	170.5	155.73
The most repeated	100-200	200-300	

3. Magnesium Ion (Mg^{+2}):

The magnesium ion (Mg^{+2}) concentration of water samples is shown in Table (8).

Table (8) The (Mg^{+2}) concentration of water samples for the old and new wells

Mg^{+2} (ppm)	Old wells	New wells	
		Dry period(October)	Wet period (April)
Range	31-298	198 - 14	12 - 198
Average	130	74.93	68.03
The most repeated	100-200	14-100	

-Major Anions:

1- Chloride Ion (Cl^-):

The chloride ion (Cl^-) concentration of water samples is shown in Table (9).

Table (9) The (Cl^-) concentration of water samples for the old and new wells

Cl^- (ppm)	Old wells	New wells	
		Dry period (October)	Wet period (April)
Range	31-746	117-1096	75 - 1050
Average	273.83	463.07	404.5
The most repeated	200-300	450-550	

2- Sulfates Ion (SO_4^{-2}):

The Sulfates ion (SO_4^{-2}) concentration of water samples is shown in Table (10) .

ISSN 2072-3875

Table (10) The (SO_4^{-2}) concentration of water samples for the old and new wells

SO_4^{-2} (ppm)	Old wells	New wells	
		Dry period(October)	Wet period (April)
Range	278-2225	110-1350	65 - 1307
Average	1211.43	613.03	546.2
The most repeated	1100-1200	500-600	

The source of sulfate ion in studied area, is from the dissolving of evaporates rocks. The decrease of sulfate ion during the wet period is due to dilution process by rainfall and change of distribution of evaporates rocks in the basin.

3- Bicarbonates Ion (HCO_3^-):

The bicarbonate ion (HCO_3^-) concentration of water samples is shown in Table (11).

Table (11) The (HCO_3^-) concentration of water samples for the old and new wells

HCO_3^- (ppm)	Old wells	New wells	
		Dry period(October)	Wet period (April)
Range	61-275	824 - 24	14 - 811
Average	136.18	223.47	210.83
The most repeated	100-200	200-300	

Groundwater Origin:

The results of the hydrochemical coefficients representing (90) selected wells (60 samples are old and 30 samples are new) indicate that most of the water samples is of marine origin, and indicated that the hypothetical salt facies are magnesium chloride $MgCl_2$ in 35 of 60 wells for the old group of wells. It is believed that these facies are inherent in the groundwater of sedimentary basins. These basins have suffered from incomplete reduction to form hydrocarbons. (Fetter, 1980). For 24 well samples among the group of the old wells the ratio of (rNa / rCl) was greater than one, hence the hypothetical salt was sodium sulfate (Na_2SO_4).

For the group of new wells, (23) well samples out of (30) show that the groundwater is of continental origin and that the hypothetical salt is sodium sulfate (Na_2SO_4) since most of this group of samples are located in the recharge zone area.

ISSN 2072-3875

It seems that groundwater of marine origin had suffered from changes in its concentration of ions after deposition as a result of mixing with rain water penetrating from the surface to the groundwater, through the faults and the fractures. The unconfined aquifers that was previously dynamic, have become isolated under impermeable cover causing them to be confined aquifers which can't be recharged from rain water directly. However recharge may be possible through the outcrop of the same layer appearing in another area. This condition is not absent in the studied area, since Umm Er Radhuma formation outcrops in the western part of the studied area near the international border with Saudi Arabian and became confined towards the Euphrates river.

- Hydrochemical classification :

(Schoeller, 1972) method was chosen due to the fact that it gives a clear idea of the sedimentation environment of Umm Er Radhuma formation and the processes that have changed the ionic concentration of water.

Depending on this classification, the quality of water in most of the selected samples are from the family of ($Ca-SO_4$) for the old wells (51 from 60 wells), while for the new samples the quality of water are from the family of (Na-Cl) in (15) samples and from the family ($Na-SO_4$) in (14) samples.

Groundwater Suitability for different purposes:

- Groundwater suitability for human drinking:

For the purpose of evaluating the suitability of groundwater of Umm Er Radhuma aquifer for human drinking, Iraqi Drinking Water Standards (IDWS, 2001) and the international specifications standard (WHO, 2007) were used to determine its usability for drinking purposes.

It could be concluded that the groundwater of Umm Er Radhum aquifer according to the values of the representative wells, is not suitable for human drinking.

-Groundwater uses for livestock:

(Altoviski, 1962),(Crist and Lowery,1972) and (Ayers & Westcot, 1994) criteria were used to determine its usability for livestock and poultry and it seems that:

1. Groundwater of Umm Er Radhuma aquifer is good for animal watering according to (Altoviski, 1962).
2. It is good for all types of animals and weak for poultry according to (Crist and Lowery, 1972).
3. It is very satisfactory for all types of livestock and unfit for Poultry, according to the classification given by (Ayers & Westcot, 1994).

- The suitability of groundwater for irrigation purposes:

Ayers and Westcot (1989) and Don (1995), classifications have been applied to determine the suitability of groundwater in the studied area for irrigation purposes. By comparing these classifications with the hydrochemical concentrations of the

ISSN 2072-3875

groundwater samples, we identify the followings:

1- Electrical Conductivity (EC):

According to the EC values for the group of old wells in Umm Er Radhum aquifer the EC of 23 wells out of 60 old wells have exceeded 3000 μmohs / cm, while 14 wells for the dry period and 10 wells for the wet period out of 30 new wells have exceeded the same value above.

EC is the main indicator of salinity, the suitability of the groundwater of this aquifer for irrigation is marginal. Some wells seem to pass over the higher suitability limit.

2- Total dissolved solids (TDS):

According to TDS values for the group of the old wells in Umm Er Radhum aquifer the TDS of 39 wells out of 60 old wells had exceeded 2000 ppm, while 14wells for the dry period and 11 wells for the wet period out of 30 wells had exceeded the same above value.

3- Cations:

all groundwater samples lie in the permissible limits for (Na^{+}), while the values of (Ca^{+2}, Mg^{+2}) for the old and new wells had exceeded the limit value.

4- Anions:

all groundwater samples lie in the permissible limits for the new wells, while for the old wells the value of (SO_4^{-2}) for 32 wells out of 60 wells had exceeded the limit value.

5- Miscellaneous:

All the samples of groundwater of the studied area came within the permissible limits regarding pH.

6- Sodium Adsorption Ratio :

The results compared with limits indicate that all values of the wells fall within the permissible limit.

7- The percentage of sodium (Na%):

The results of Na% of Umm Er Radhuma aquifer compared with the suggested limits reveal that all values of wells fall within the permissible limit, with the exception of six of the new wells which fall within the doubtful limit.

-Groundwater suitability for industrial purposes:

Requirements for the quality of water used in different industrial processes are different and almost every industrial application have its own standards (Hem, 1991).

The results of comparing the quality of Umm Er Radhuma aquifer to these suggested limits show that groundwater is not suitable to all types of industries.

- Groundwater suitability for building purpose:

The classification suggested by (Altoviski, 1962) has been adopted to be compared with the quality of the groundwater of Umm Er Radhuma aquifer. The comparison indicates that groundwater is suitable to be used for building purposes.

ISSN 2072-3875

Conclusions :

These results were as follow:

- (EC) values of water samples for the new wells range from (1445 µmohs/cm) to (7790 µmohs/cm) with an average value (3058.2 µmohs/cm) for the dry season (October) and from (1235µmohs/cm) to (7280 µmohs/cm) with an average value (2783.8 µmohs/cm) for the wet season (April).
- (TDS) values of water samples for the new wells range from (1090 mg/l) to (6000 mg/l) with an average value (2161.17 mg/l) for the dry season (October) and from (1050 mg/l) to (5870 mg/l) with an average value (2002 mg/l) for the wet season (April).
- (PH) values for the new wells of Umm Er Radhuma range between (7.08-8.8) with an average of (7.7).
- (Na^{+}) concentration of water samples from the new wells ranges from (72 mg/l) to (1000 mg/l) with an average value (347.97 mg/l) for the dry season (October) and from (42 mg/l) to (948mg/l) with an average value (299.87 mg/l) for the wet season (April).
- (Ca^{+2}) concentration of water samples for the new wells ranges from (38 mg/l) to (389 mg/l) with an average value (170.5 mg/l) for the dry season (October) and from (34 mg/l) to (375 mg/l) with an average value (155.73 mg/l) for the wet season (April).
-(Mg^{+2}) concentration of water samples for the new wells ranges from (14 mg/l) to (198 mg/l) with an average value (74.93 mg/l) for the dry season (October) and from (12 mg/l) to (198 mg/l) with an average value (68.03 mg/l) for the wet season (April).
-(Cl^{-}) concentration of water samples for the new wells ranges from (117 mg/l) to (1096 mg/l) with an average value (463.07 mg/l) for the dry season (October) and from (75 mg/l) to (1050 mg/l) with an average value (404.5 mg/l) for the wet season (April).
-(SO_4^{-2}) concentration of water samples for the new wells ranges from (110 mg/l) to (1350 mg/l) with an average value (613.03 mg/l) for the dry season (October) and from (65 mg/l) to (1307 mg/l) with an average value (546.2 mg/l) for the wet season (April).
- (HCO_3^{-}) concentration of water samples for the new wells ranges from (24 mg/l) to (824 mg/l) with an average value (223.47 mg/l) for the dry season (October) and from (14 mg/l) to (811 mg/l) with an average value (210.83 mg/l) for the wet season (April).

The results of determining the hydrochemical coefficient for the (90) selected wells (60 samples for the old group of wells and 30 samples for the new ones) show the following:

- For the 60 old group of wells, the groundwater is found to be of marine origin, with the hypothetical salt consisting of magnesium chloride ($MgCl_2$) in 35 well samples and sodium sulfate (Na_2SO_4) in 24 well samples. For the 30 group of new wells located in the recharge area, (14) well samples show that groundwater is of continental origin with the hypothetical salt consisting of sodium sulfate (Na_2SO_4).

It is concluded that the groundwater is of marine origin, but had suffered from changes in the concentrations of its ions after deposition as a result of mixing with rain

ISSN 2072-3875

water penetrating from ground surface during periods of non-conformity. The classification of groundwater according to (Schoeller) method shows that most of the groundwater of the old group of wells consists of ($Ca\text{-}SO_4$) (52 out of 60 wells), while it is of two types (Na-Cl and $Na\text{-}SO_4$) for the new group of wells .

- Considering the groundwater suitability for human drinking using WHO(2007) and IQS(2001) standards, it was found that it is not suitable.
- The groundwater is considered good for animal drinking according to (Altoviski, 1962) standard, it is good for all types of animals, but poor for poultry according to (Crist and Lowery, 1972) and very acceptable for all types of livestock and unfit for poultry according to the classification given by (Ayers & Westcot, 1989).
- For agricultural purposes, the groundwater of Umm Er Radhuma aquifer is suitable for most types of summer and winter crops because the salinity of the water is within the permissible limits when considering the nature of the soil.
- Groundwater exploitation of Umm Er Radhuma aquifer depends on the quality of the groundwater and its suitability for agriculture by comparing the concentrations of its main elements and salinity with the standard specifications. From this comparison, it is concluded that some of the water of the aquifer is not valid, and over the permitted limits, but this water is used for agriculture in large areas of the desert and it is give a special feature because of the nature of the soils and its high permeability as well as the rapid drying due to the high temperatures of the desert which requires the continuity of the irrigation operation. The deep groundwater and the thickness of soil prevent deposition of salts around the roots of the plants.
- The groundwater is not suitable for industry, but it is suitable for building according to the available standards.
- The best water quality in Umm Er Radhuma aquifer is found in the recharge zone at the western edge of the aquifer where it is recharged by Wadi Horan. The groundwater TDS value ranges between (1000 – 2000) ppm, increasing with the flow direction toward the east and the southeast until it attains a value of about 5000 ppm in the discharge zone in the east of Umm Er Radhuma aquifer.

References :

Altovisiki, M. E., 1962: Hand book of hydrogeology. Geogoelitzet, Moscow, USSR (In Russian), 614p.

Ayers, R. S. and Westcot, D. W. 1989: Water quality for agriculture. Irrigation and drainage paper 29, Rev.1. FAO, Rome, Italy, 174p.

Ayers, R.S. and Westcot, D.W. , 1994 : Water Quality for agriculture. Irrigation Drainage Paper 29, Rev. 1, FAO, Rome, Italy, 174p. Crist, M.A. and Lowry, M.E., 1972: Groundwater resource of Natrona county wyming, A study of the availability and

ISSN 2072-3875

chemical quality of groundwater, Geological Survey Water Supply, Paper 1897, U.S. Government Printing office, Washington, 92p.

Detay, M., 1997: Water Wells- implementation, maintenance and restoration, John Wiley and Sons, London, 379p.

Don, C.M., 1995: A grows guide to water quality. University college station, Texas.

Drever, J.I., 1997: The geochemistry of natural water, surface and groundwater environments, (3rd ed.), Prentice Hall, USA, 436P.(2nd ed.). Prentice Hall Inc, USA, 600p.

Fetter, C. W., 1980: Applied hydrogeology, Charles Merrill pub. Co. A. Bell and Howell company, Columbus, Ohio, 488p.

Hem, J.D., 1991: Study and interpretation of the chemical characteristics of natural water. USGS Water Supply. Paper no. 2254, 263p.

IDWS, 2001: Iraqi Drinking Water Standards, Central Organization for Standardization and Quality Control, Min. of Planning .

IGS, 1998: Iraqi Guidelines Standard for Drinking water, (in Arabic).

Schoeller, M., 1972: Etude geochemical de la nappe dess in Ferieures dubas d' Aquitaine Journal of Hydrology, vol.15, No. 3, pp.317-328.

Todd, D. K., 1980; Groundwater hydrology second edition, Jhon Wiley and Sous, Inc. New York. 535p.

Todd, D. K., 2007: Groundwater hydrology third edition, Jhon Wiley and Sous, Third Reprint. Inc. India. 535p.

Walton, C.W., 1970: Groundwater Resource Evaluation Mc Graw Hill Co., 664.

World Healthy Organization(WHO), 2007: Guidelines for Drinking Water Quality. 3th ed., Vol.1, Recommendations, Geneva, 595p.

ISSN 2072-3875