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Assessment of the Groundwater of UmErdhuma-Tayarat Aquifer for Various Purposes and Uses

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Abstract

Introduction: A groundwater quality investigation has been carried out within Kasra-Nukhaib district (west Iraq), The physicochemical analyses of twenty-four groundwater samples collected from UmErdhuma-Tayarat Aquifer are used in the determination of groundwater assessment for various uses supported by standard limits for various purposes. In the interiors area restricted to Habbariyia-Nukhaib depression, UmErdhuma-Tayarat aquifer is of unconfined condition with saturation thickness ranged from 52 to 150 m. The amount of permeability for the water-bearing horizons of UmErdhuma-Tayarat aquifer ranged between 0.1 m/day and 14.7 m/day.

Materials and Methods: The groundwater monitoring program in 24 wells was carried out within the scope of the Habariyia depression during the 2013 water year. The coordinates are set by Garmin GPS. Conceptual spatial hydrochemical bi-model was prepared for quantitative and qualitative interpretation. The hydrochemical results are correlated with the standard classifications to determine the hydrogeochemical phenomena for groundwater use. The sodium percent of the groundwater samples on the Wilcox diagram indicates that the Groundwater is good to permissible quality for irrigation uses in the twenty-one percentile, of the samples, doubtful to unsuitable in sixty-seven percentile

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and unsuitable in twelve percentile.

Results: SAR values on Richards diagram show that 50% of the water samples are classified as admissible to good quality for irrigation. The other water samples are classified as bad to very bad. The results showed that the groundwater of the UmErdhuma-Tayarat aquifer has precedence for irrigation, agricultural purposes, animal drinking, and fair class for natural preserve activities, while the groundwater of the aquifer is not suggested for direct drinking purposes. In addition, the groundwaters within the hydrogeologic system can be used in low-pressure boilers, mining, construction industry, and unsafe in high-pressure boilers.

Conclusions: Saturated indices of gypsum and anhydrite confirm that the groundwater is still active to leach sulfate ions from theb gypsum and anhydrite minerals phase. The concentration of magnesium and calcium are originated from the weathering of carbonate and evaporite rocks (limestone, dolomite, and gypsum). In the majority of the groundwater samples, each borehole sampled had at least one constituent that exceeded the Human drinking-water standard set by World Health Organization, and Maximum Contaminant Levels set by the US Environmental Protection Agency. Concentrations of TDS, H_T, and major ions exceed the desirable limit in most samples and require treatment before its utilization. Suitable water treatment processes such as water softening, ion exchange, and demineralization should be applied to reduce the concentration of ions. The analyzed parameters of the water samples are within the prescribed limits for animal drinking purposes, therefore, the groundwater is potable for use and classified as good to fair class for natural preserve activities. Quality assessment for irrigation suitability confirms that the groundwater belongs to the moderate class and can be used for irrigation. High values of salinity, residual sodium carbonate, sodium adsorption ratio, and sodium percent at some sites restrict the suitability of groundwater for agricultural purposes and demands special management plans for the area.

The Corrosivity ratio indicates that 75% of exploited groundwater from boreholes is unsafe for long-distance transportation through metallic pipelines.

Keywords: Groundwater uses, Hydrochemical criteria, Standards limits, Groundwater quality.

1. Introduction

The study region is located between longitude 42º 00' 00" to 42º 30' 00" and latitude 32º 00' 00" to 32º 30' 00" with a total area of 2,600 km^2 and elevation ranges between 280 and 360 m above sea level (Figure 1). The study aims to determine the geochemical assessment of the groundwater of the UmErdhuma-Tayarat aquifer by evaluating the hydrochemical characteristics of the groundwater for suitable uses and purposes. Spatial variation interpretation is used to identify the chemical characteristics of the groundwater. The area is characterized by the dry desert climate where the mean annual values of rainfalls do not exceed 50 mm in some dry years and little quantities of water may flow. The study region has an undulating terrain with a land surface slope that varies between 0.4 and 13 m/km from the northwest direction to the southeast direction. Several valleys of seasonal flux forming plateaus with pediment deposits (Hamza, 1997) and depression filled with sediments such as Habbariyia, Shabwan, and Khubrit Adhad. The valleys are defined as main landforms including Ubayidh valley and Tebal valley with its tributaries (Mdaycice, Abu Ghar, Shabwan, and Dwaykhla), these valleys form important drainage basins as groundwater recharge zone for Um Erdhuma-Tayarat aquifer (Figure 1).

The valleys and depressions fill sediments are considered important geomorphologic units. The depressions fill sediment overlies varying areas originated to the leaching of fractured dolomite and limestone rocks, where active runoff contributes to filling depressions by sands, mud, and silts .These valleys are characterized by expanding widths, the presence of gravels aggregates, karst sinkholes, and the presence of meandering valleys with many breaks off in their long sectors. In Habbariyah Depression, three stages of alluvial fans are developed.

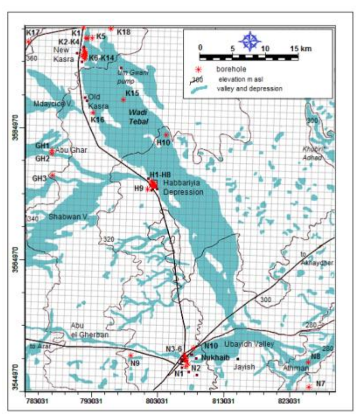

Fig. 1. Location map of the study region

Structurally, the study area is located in the SE limb of Hauran anticlinorium (Rutba Uplift) (Jassim & Goff, 2006). The uplift contributed to the tectonic movements within successive geological periods affects the structural and stratigraphic settings within Nukhaib Graben. Al-Mubarak & Amin (1983) described the N-S trending faults as a set of normal faults systems with many kilometers in wide forming Nukhaib Graben. Al-Bassam et al. (2000) presented a geologic discussion concerning the origin of Graben. They pointed out that the graben is formed above the basement high of granitic intrusion and/or a salt dome.

Geological studies of (Buday & Hack, 1980; Al-Mubarak & Amin, 1983; Jassim et al., 1984; Al-Azzawi & Dawood, 1996; Sessakian & Mohamed, 2007) are summarized in a surface Geologic map (Figure 2), where the study area includes Quaternary sediments, Zahra Formation, Dammam Formation, UmErdhuma Formation, Tayarat Formation, etc. More details for a geologic section are mentioned in Table 1.

Groundwater occurs in karstic fractured carbonate rocks belonging to Late Maastrichtian-Danian Formations (UmErdhuma-Tayarat aquifer). Regionally, al Hamad physiographic zone is considered as a main recharge zone of the aquifer within the study area (Araim, 1990; Hussien, 2010), these studies confirmed a practical occurrence of recharge and water replenishment renewed aquifers by rain and runoff waters penetrated throughout rocks exposures within the valleys. Locally, the UmErdhuma-Tayarat aquifer is recharged from the Tebal-Ubayidh catchment area and lateral leakage of waters passing as a result of the hydraulic connection between adjacent aquifers. The amount of infiltration penetrated to UmErdhuma-Tayarat aquifer within the study region is equal to 6188000 m^3/year (Hussien & **Faiyad**, 2015). In the interiors area restricted to Habbariyia-Nukhaib depression, UmErdhuma-Tayarat aquifer is of unconfined condition with saturation thickness ranged from 52 to 150 m. The amount of permeability for the water-bearing horizons of UmErdhuma-Tayarat aquifer ranged between 0.1 m/day and 14.7 m/day. The aquifer is classified as an aquifer of low to middle permeability (Hussien & **Faiyad,** 2015).

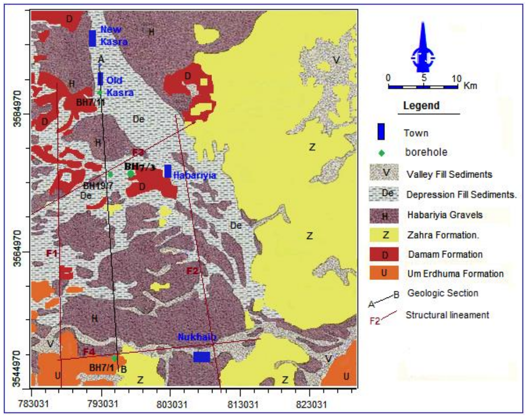

Fig. 2. Spatial distribution map of the Geologic Formations

Tab. 1. Geologic Information of Kasra-Nukhaib region

Cenozoic	**Quaternary**	Holocene-Pleistocene	Recent deposits	Alluvial sediments, valley, and depression fill sediments.
		Pleistocene	Habbarriya Gravel	sandy Gravel, Conglomerate
	Tertiary	Late Miocene-Pliocene	Zahra Formation	Limestone, calcareous sandstones with hard recrystallized carbonates
		Lutetian	Dammam Formation	Fossiliferous limestone and dolomitic limestone alternations with clays chalky and cherty limestone
		Danian	Um Erdhuma Formation.	Phosphatic limestone, dolomite, dolomitic limestone, and thin beds of anhydrite.
Mesozoic	**Cretaceous**	Late Maastrichtian	Tayarat Formation	Limestone, yellow marl, dolomite, dolomitic limestone, and phosphatic siliceous limestone.
		Late Campanian-Early Maastrichtian	Hartha Formation	Sandy limestone, dolomitic limestone and clayey dolostone interbedded with marly limestone.
		Turonian-early Campanian	Sa'adi Formation	Chalky fossiliferous limestone, marly limestone, and organic limestone.
		Cenomanian-Turonian	Msad Formation	Coralline limestone, multi-colored sandy dolostone, sandy marl and dolomitic limestone.
		Cenomanian	Rutba Formation	Sandstones alternating with clayey silty sands obtained coarse sands and basal conglomerate.
	Jurassic	Bathonian	Muhaywir Formation	dolomitic sandstone alternated with fine ferruginous sands, limestone, marly limestone with conglomerate and cherty claystone.

The amount of transmissivity of the UmErdhuma-Tayarat aquifer ranged between 15 m^2/day and 800 m^2/day. The aquifer is classified as an aquifer of middle to high transmissivity, where the transmissivity value decreases within Habbariyia depression and decreases in the vicinity of Nukhaib (Hussien et al. 2014).

The groundwater of Um Erdhuma-Tayarat aquifer is controlled by unconfined conditions, where the amount of storativity ranged from 10^{-3} to 5×10^{-2}. The results of the storage coefficient show low variation in values originated from the same geostructural settings and rocks characteristics. The spatial distribution variation of storativity (Figure 3) shows an increase in storativity variation grade ranged between 3.7×10^{-8} and 3.2×10^{-5} per meter distance towards Habbariyia extensions, whereas storativity value decreases in the vicinity of Nukhaib in the south part and new Kasra in the north portion. The wells within the study area are classified within the wells of medium-very high productivity. The specific capacity of the water wells ranged between 1.8 and 21.1 lit/sec/m within wells depths ranging from 125 m to 538 m.

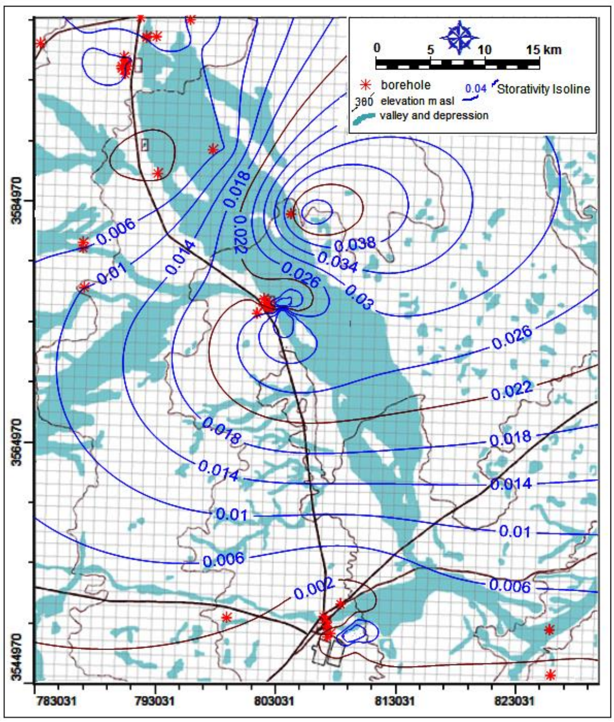

Fig. 3. Spatial variation map of storativity

The groundwater within UmErdhuma-Tayarat aquifer moves from the west and southwest portions in the area that existed west Nukhaib graben and also flows from the northern portion in the area located northeast Nukhaib graben towards the Habbariyia region and its suburbs area. This region represents a groundwater discharge zone due to intense exploitation and/or deep percolation throughout buried sinkholes and karst passages forming a boundary of the captured zone. The groundwater flows under the effort of the hydraulic gradient ranged from 0.000011 (11 cm/10 km) to 0.007 (7 cm/10 m), the rate of groundwater flux ranged between 0.00000012 cm/day (Hussien & Fayyadh, 2015). The Total Dissolved Solids of the groundwaters ranged from 1028 to 2730 mg/L. Therefore the groundwaters are classified as slightly saline water according to TDS classification (Matthess, 1982; Collin's, 1975). The distribution map of TDS (Figure 4), shows an increase of concentration in a leaching grade of 0.0008 to 0.62 mg/lit/m to the scope of Habbariyia village corresponding with the flow direction.

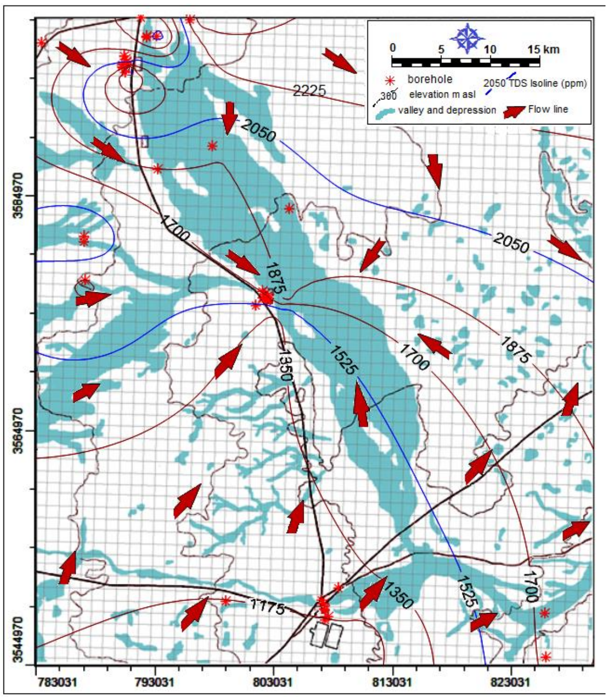

Fig. 4. Spatial distribution map of TDS compiled with groundwater flow (Hussien & **Faiyad**, 2015)

Alfji et al. (2016) found according to chemical analysis, The electrical conductivity (EC) which is an index to represent the total concentration of soluble salts in water was used to measure the salinity hazard to crops as it reflects the TDS in groundwater ranging from 1056 to 8320 μmhos/cm. In general, Na^+ is the dominant cation, and Cl^- is the dominant anion. Cl-Na.Ca and Ca.Mg-Cl were the dominant hydrogeochemical faces, and Wilcox classification suggested that the groundwater unsuitable for drinking and irrigation purposes.

Alaizari (2018), Study Physical and chemical properties for water in Wadi

Almawaheb and Qa' Asawad for classification of this water for irrigation use, where it was adopted on cations ions (Calcium (Ca^{2+}), Magnesium (Mg^{2+}), sodium (Na+), Potassium (K^{+}), anions ions (bicarbonate ($HCO3^{-}$), Chloride (Cl^{-}), Sulfate ($SO4^{2-}$), pH value, Electrical Conductivity (EC), and Sodium Adsorption Ratio (SAR), the results showed that, 50% water samples fall within the water class (C3-S1) and 50% water samples fall within the water class (C2-S1) according to USSL system. Whereas in the FAO system, the samples fell within the class (increase in salinity hazard) for the salinity hazard, In addition, pH values were within natural limits.

Ali (2017), study to assess the hydrological situation of the groundwater reservoir west of Samarra by using the pumping test data in the individual wells to determine the values of the Transmissivity (T) (51.8 m^2/day) east of the study area, gradually decreasing to (5.3 m^2/day) west of the study area. The values of the hydraulic conductivity (K) reached (1.23 m/day) east of the study area and gradually decreased to (0.119 m/day) west of the study area.

Results revealed by Abd El-Aziz (2017), In his study of the area of Libya (Aligeelat), that most groundwater samples were not suitable for drinking and household uses due to their high levels of most cations and anions, total hardness, EC and TDS. Most of the collected water samples showed the investigated parameter levels exceeded the permissible limits of WHO. Therefore, most of the groundwater samples are considered unsuitable for irrigation due to its high salt content, unless certain measures for salinity control are undertaken.

2. Materials and Methods

The groundwater monitoring program in 24 wells was carried out within the scope of the Habariyia depression during the 2013 water year. The coordinates are set by Garmin GPS. The collection of groundwater samples from wells were achieved according to the field procedures explained in (Shelton, 1994). All tools and containers were washed with distilled water, then bottles rinsed with sample water before packing to ensure the elimination of pollutants (Shafer et al., 1997; Hem, 1990). Groundwater pH and electrical conductivity are measured using calibrated EC-pH meters with standard solutions.

Quality criteria of water for domestic use, drinking, Livestock, irrigation, industrial and other purposes have been proposed by various national and international agencies such as World Health Organization (WHO, 2006) and US Environmental Protection Agency, USEPA (2002), (Table 2).

Tab. 2. Standard limits for using water for various purposes.

Constituents	Drinking			Animal Watering Crist and Lowry, 1972	
	European Union 1998	USEPA 2002	WHO 2006	TDS mg/L	Class
pH	-	6.5-8.5	7-8.5	0-1000	Good
TDS (mg/L)	-	500	500		
K (mg/L)	-	-	-	1000-3000	Fair
Na (mg/L)	200	-	200		
Ca (mg/L)	-	-	75	3000-5000	Bad
Mg (mg/L)	-	-	30		
HCO_3 (mg/L)	-	-	200	5000-7000	V.bad
Cl (mg/L)	250	250	250		
SO_4 (mg/L)	250	250	200	7000-13000	Un-suitable
NO_3 (mg/L)	50	44	50		
H_T(mg/L)	-	-	500		

Chemical composition reliability was checked using the charge balance method (Fitts, 2002). The chemical analyses of anions, cations, total dissolved solids (TDS), Total Hardness, and field measurements are scheduled in Table 3. Groundwater samples were analyzed in the Soil and Water Laboratory (Centre of the desert studies). The concentrations of the chemical constituents of the groundwaters in aquifers are correlated with the various quality criteria to identify the probability of use. SAR (Sodium Adsorption Ratio) is an estimate of the extent to which sodium ion present in the water would be absorbed by the soil and is expressed by the equation:

$$SAR=Na/\sqrt{\{(Ca+Mg)/2\}} \qquad (1)$$

The SAR value recommended for irrigation should not be higher than 20 and preferably less than 10, or as hereinafter classification; SAR: 1-10 low sodium hazard; SAR: 10-18 medium sodium hazard; SAR: 18-26 high sodium hazard; SAR>26 very high sodium hazard. SAR criteria against salinity in the USSLS diagram is used for irrigation application (agriculture purpose), (USSLS, 1954).

Sodium Percentage Na% was calculated as Na%=100(Na+K)/(Ca+Mg+Na+K). The ratio of sodium and potassium in the sum of cations is an important factor in considering water for agricultural uses. The distribution of Na% classification was used as excellent good, Permissible, Doubtful, and Unsuitable category shows that the percent of sodium (Na%) content is a parameter to assess its suitability for agriculture purposes (Wilcox, 1955).

Groundwater was evaluated for animal drinking water purposes using the US. Public Health Service classification, (Crist & Lowry, 1972; Lewen & King, 1971). The quality requirements for industrial water supplies range widely, and every industrial application has its standards. Water containing TDS values of less than 500 mg/L is suitable for most industrial uses.

For some uses such as single-pass condensing of steam or for cooling or for concentrating ores, chemical quality is not particularly critical and almost any water may be used. Water used for processing food or beverages must also meet drinking water standards. It is technically possible to treat any water to give it a composition suitable for special uses. At the opposite extreme, water approaching or equaling the quality of distilled water is required for processes such as the manufacture of high-grade paper or pharmaceuticals, where impurities in the water would seriously affect the quality of the product. Some ideas as to the varied nature of the requirements for certain industries can be obtained from data presented by the U.S. Federal Water Pollution Control Administration (Walton, 1970).

3. Results and Discussion

The chemical composition of water is important, as certain chemical constituents become toxic beyond a particular concentration although they may be beneficial in a lower amount. Standards for drinking water vary among countries, depending upon economic conditions, climate, food habits. Drinking water standards recommended by European Union, US Environmental Protection Agency USEPA (2002) and WHO (2006), (Table 2), are used for assessment further the potability of water in terms of TDS as suggested by (WHO, 1984): Excellent <300 mg/L, Good 300–600 mg/L, Fair 600–900 mg/L, Poor 900–1200 mg/L, Unacceptable >1200 mg/L.

Water Quality Standards for Use by Livestock and domestic purposes are fundamental, the same standards thet can be applied to human beings. The quality criteria of water for industrial purposes depend on the type of industry, processes, and products. In the construction industry, the sulfate content of water is important to avoid the deterioration of concrete. The quality standards for irrigation water cannot be applied very rigorously as in the absence of water of required quality, poor quality water can also be used in farming by making necessary water management practices. The earliest systems of water classification in irrigation use were given by Wilcox (1955) and USSLS (1954).

3-1. Portability of Groundwater for Human Drinking and Domestic Uses

To ascertain the potability of groundwater for drinking and domestic purposes, the analytical results of the groundwater within the UmErdhuma-Tayarat aquifer (Table 3) have been compared with the standard guideline values recommended by the World Health Organization (WHO, 2006). The comparison indicates that:

✓ The pH of the groundwater samples is well and within the safe limit of 6.5-8.5.

✓ The total dissolved solids exceeded the desirable limit (500 mg/L), classified as poor to unacceptable water in all of the groundwater samples.

✓ The total hardness value of the analyzed subsurface water exceeds the desirable limit of 300 mg/L in all samples and the maximum permissible limit (500 mg/L) in 87% of samples.

✓ The HCO_3 concentration exceeds the desirable limit (200 mg/L) and Cl (250 mg/L) in 54% of the groundwater samples. A higher concentration of Cl in drinking water gives a salty test.

✓ The SO_4 concentrations are exceeding the maximum permissible limit (200 mg/L) in all groundwater samples. A higher concentration of SO_4 in drinking water has a laxative effect.

✓ The Na concentration exceeds the recommended level (200 mg/L) in about 54% of the groundwater samples. Na concentration is an important ion for human health. A higher sodium intake may cause heart diseases, nervous disorders and kidney problems.

✓ The magnesium concentrations are exceeding the maximum permissible limit (30 mg/L) in all groundwater samples. While calcium concentrations are well within the maximum permissible limit of 75 mg/L in 16% samples, though it exceeds the desirable limit in 84% samples.

3-2. Portability of Groundwater for Animal Drinking Uses

The concentration of groundwater salinity within the UmErdhuma-Tayarat aquifer (Table 3) has been compared with the Water Quality Standards for Livestock Use recommended by Crist & Lowry, (1972). The comparison indicates that the groundwater of the aquifer is fair and within the safe limits in 96% of the groundwater samples. Also, Animals can have a greater tolerance of total dissolved solids, may reach 3000 mg/L to 10000 mg/L, e.g. poultry, camels, sheep, horses, dairy cattle and beef cattle according to specific classification in Lewen & King (1971).

3-3. Portability of Groundwater for Industrial Uses

The quality criteria of water for use in boilers is important as water used in high-pressure boilers should be free from suspended matter and should have low total dissolved solids. Low-pressure boilers can use water with total dissolved solids up to 5000 mg/L and $CaCO_3$ hardness up to 80 mg/L, therefore the groundwater within UmErdhuma-Tayarat aquifer can be used in this employ, while in high-pressure boilers total dissolved should be less than 50 mg/L and hardness less than 1 mg/L, accordingly, the groundwaters are not recommended for this use. In the construction industry, the sulfate content of water is important to avoid the deterioration of concrete. Comparing with the recommended maximum permissible limit for the existence of SO_4 in the groundwaters (1500 mg/L) proceeded by Altoviski (1962), the SO_4 concentration was not exceeded the maximum desirable limit in all groundwater samples except in borehole K16. The corrosivity ratio (CR) denotes the susceptibility of groundwater to corrosion and is expressed as the ratio of alkaline earth to saline salts in groundwater. The effects of corrosion are losses in the hydraulic capacity of pipes. The corrosivity ratios expressed as, $CR= (Cl+SO_4)/\{2(HCO_3+CO_3)\}$, (Golekar et al., 2014) were observed to range from 0.67 to 3.66 in the groundwater of the study region (Table 4). The corrosivity ratio indicates that 25% of exploited groundwater from boreholes are safe (CR<1) against metallic materials and 75% are unsafe (CR>1). The majority of water is unsafe for long-distance transportation through metallic pipelines, but in the unsafe quality, PVC pipes should be used for water supply.

Tab. 3. Field measurements and Chemical analyses of the groundwater within the study area

Station ID	X coordinatem	Y coordinatem	pH	EC µS/cm	TDS mg/L	H_T mg/L	NO_3 mg/L	K^+ mg/L	Na^+ mg/L	Mg^{++} mg/L	Ca^{++} mg/L	Cl^- mg/L	$SO_4^=$ mg/L	HCO_3^- mg/L
H1	802476.595	3575971.446	7.1	2290	1510	883.4	16.49	12.28	99.1	144.28	116.74	284	337.44	512.48
H2	802654.2798	3576161.809	6.9	2958	1836	1125.6	16.51	7.92	119.7	200.4	121.6	213	538.37	634.504
H4	802419.6285	3576123.936	7.0	2994	2023	892.2	16	26.9	363.8	117	165	488.8	793	251.9
H6	802302.9311	3576521.354	7.2	2239	1860	1084.2	16.35	31.73	145	184.36	131.33	248	710.88	439.27
H7	802084.3165	3576823.203	7.1	2284	1877	1084	16.42	24.61	144.2	184.36	131.33	213	763.2	414.86

Station ID	X coordinatem	Y coordinatem	pH	EC μS/cm	TDS mg/L	H_T mg/L	NO_3 mg/L	K^+ mg/L	Na^+ mg/L	Mg^{++} mg/L	Ca^{++} mg/L	Cl^- mg/L	$SO_4^=$ mg/L	HCO_3^- mg/L
H9	801545.3265	3575573.513	7.1	1541	1385	703.3	16.44	34.49	130.2	112.22	97.28	248	371	390.46
N1	807385.3354	3548825.99	7.1	1899	1028	547.5	16.44	17.61	77.2	80.16	87.552	71	309.3	384.3
N4	807225.3003	3549777.193	6.95	1599	1269	1194.9	16.32	32.4	60.1	256.51	57.28	242.1	511.64	457
N8	825839.4548	3549337.681	7.1	2506	1881	1193.4	16.0	10.9	97.98	100.1	313.2	141	993.6	225.09
K1	791896.5188	3600175.252	7.2	2298	1626	425.9	16.8	45.74	332.52	80.16	38.91	284	340.69	542.9
K3	792336.7511	3598522.871	7.25	2192	1535	417.4	17.4	44.78	336.77	72.14	48.64	248	474.41	292.84
K5	793197.6383	3598578.875	7.2	2293	1458	441.7	17.37	49.57	269.56	72.14	58.36	248	491.86	268.44
K7	790510.0965	3596619.503	7.0	2783	2061	878.4	16.98	76.38	402.77	128.25	141.05	603	375.58	317.25
K8	790646.9483	3596407.613	7.3	3142	2215	1303.5	16.79	39.03	102.52	198.66	195.59	319	893.6	244.04
K9	790675.7491	3596315.937	7.3	2167	2042	687.5	16.5	50.53	377.89	120.24	77.82	426	465.69	524.6
K10	790733.3518	3596132.586	6.9	2170	2055	826.7	16.58	46.69	310.5	127.5	121.6	426	500.58	524.6
K11	790611.6809	3595820.689	7.2	3772	2730	869.9	16.39	65.85	517.02	120.24	150.78	710	518.02	646.6
K13	790267.6406	3595964.905	7.3	2607	2150	906.1	16.54	71.59	321.0	102.83	193.8	639	503.48	317.25
K15	797867.544	3589187.423	7.0	2553	1886	618.4	16.55	44.78	367.65	91.52	97.28	497	494.76	292.84
K16	793216.2871	3587200.379	7.1	6239	5831	859	16.53	62.02	1511.3	144.28	107	426	2910.4	671
K17	783490.9836	3598021.899	7..2	1599	1724	807.3	16.4	30.41	214.6	103.56	153.1	319.5	512.2	390.4
K18	795971.5966	3600000.245	7.1	3745	2479	975.7	15.64	62.02	374.9	128.25	179.96	568	483.13	683.2
GH1	787099.8591	3581473.541	7.2	1780	1346	696.3	15.0	7.41	115.7	77.58	151.3	68.52	501	424.5
GH3	787205.1743	3577776.348	7.3	2258	1740	1089.9	15.0	20.7	84.4	86.2	294.6	167.5	831	256

Tab. 4. Hydrochemical indices for the groundwater use within the study region.

Well No.	X coordinatem	Y coordinatem	Hydrochemical Indices				
			CR	Na%	SAR	RSC	KI
H1	802476.595	3575971.446	0.89	20.7	1.45	-9.29	0.26
H2	802654.2798	3576161.809	0.83	19.32	1.55	-12.15	0.24
H4	802419.6285	3576123.936	3.66	47.99	5.29	-13.75	0.92
H6	802302.9311	3576521.354	1.51	24.67	1.91	-14.51	0.32
H7	802084.3165	3576823.203	1.61	24.1	1.9	-14.92	0.31

Well No.	X coordinatem	Y coordinatem	Hydrochemical Indices				
			CR	Na%	SAR	RSC	KI
H9	801545.3265	3575573.513	1.15	31.74	2.13	-7.68	0.46
N1	807385.3354	3548825.99	0.67	25.79	1.43	-4.66	0.34
N4	807225.3003	3549777.193	0.91	12.55	0.75	-14.44	0.14
N8	825839.4548	3549337.681	3.34	15.98	1.23	-20.16	0.19
K1	791896.5188	3600175.252	0.85	64.69	7.0	0.37	1.83
K3	792336.7511	3598522.871	1.75	61.38	5.93	-3.56	1.59
K5	793197.6383	3598578.875	1.95	59.74	5.57	-4.45	1.47
K7	790510.0965	3596619.503	2.38	41.48	3.54	-12.39	0.71
K8	790646.9483	3596407.613	3.45	17.32	1.23	-22.1	0.21
K9	790675.7491	3596315.937	1.26	56.28	6.26	-5.17	1.28
K10	790733.3518	3596132.586	1.3	47.02	4.69	-7.96	0.88
K11	790611.6809	3595820.689	1.45	58.12	7.62	-6.81	1.39
K13	790267.6406	3595964.905	2.73	46.55	4.63	-12.93	0.87
K15	797867.544	3589187.423	2.53	58.04	6.42	-7.58	1.38
K16	793216.2871	3587200.379	3.3	79.63	22.39	-6.21	3.9
K17	783490.9836	3598021.899	1.53	38.48	3.28	-9.76	0.62
K18	795971.5966	3600000.245	1.16	47.8	5.22	-8.33	0.91
GH1	787099.8591	3581473.541	0.88	26.97	1.9	-6.97	0.37
GH3	787205.1743	3577776.348	2.62	16.0	1.11	-17.59	0.19

Residual Sodium Carbonate (RSC) = $(CO_3+HCO_3) – (Ca+Mg)$;
Corrosion ratio (CR)=$(Cl+SO_4)/\{2(HCO_3+CO_3)\}$; Sodium adsorption ratio (SAR)= $Na/\sqrt{[(Ca+Mg)/2]}$
Sodium percent (%Na) = Na+K (100)/(Ca+Mg+Na+K); Kelly index (KI) = (Na+K)/(Ca+Mg).

3-4. Suitability of Groundwater for Irrigation Uses

The total salt concentration, sodium percentage (%Na), residual sodium carbonate (RSC), sodium adsorption ratio (SAR), and Kelley index (KI) are the important parameters used for assessing the suitability of water for irrigation uses (Ayers & Westcot, 1985). The computed values of these parameters are listed in Table (4) and all ionic concentrations used for calculation are expressed in meq/L.

3-4-1. Residual sodium carbonate (RSC)

The concentration of bicarbonate and carbonate over alkaline earth metal cations, which are expressed as residual sodium carbonate (RSC)= $(CO_3+HCO_3)-(Ca+Mg)$, are affecting the water quality for irrigation purposes (Karanth, 1989). The existence of HCO_3 and CO_3 in irrigation water assist to precipitate calcium and magnesium ions in the soil. This may cause an increase of in sodium ions. Therefore, RSC was considered as indicative of the sodicity hazard of water. Groundwaters having RSC values greater than 2.5 meq/L are unsuitable for irrigation. RSC value between 1.25 and 2.5 meq/L is considered as the marginal quality and value <1.25 meq/L as the safe limit for irrigation. Calculated RSC values in (Table 4) show that all analyzed groundwater of UmErdhuma-Tayarat aquifer were below 1.5 meq/L. That means the groundwater is suitable for irrigation purposes.

3-4-2. Kelley's index (KI)

Kelley's index is the ratio of Na^+/(Ca+Mg) which is used for the classification of water for irrigation. Water with Kelley's ratio of >1.0 indicates an excess level of sodium and is unsuitable for irrigation. Whereas ratios of <1.0 refer to suitable for irrigation (Kelley, 1946). KI values in the groundwater of the UmErdhuma-Tayarat aquifer varied from 0.14 to 3.9 (Table 4).

The KI values in 71% of the groundwater samples are <1.0, Which means suitable for irrigation. While 29% of the groundwater samples exceeded the specified limit (KI>1.0) classifying it as unsuitable for irrigation.

3-4-3. Sodium percentage (Na%)

Salinity and sodicity are the most important parameter of water quality concerns in irrigated areas of arid and semi-arid regions. The effects of salinity and sodicity on soils include a change in, soil structure, permeability, and aeration, which indirectly affect plant growth. The concentration of total soluble salts in irrigation water can be expressed as low (EC=<750 µS/cm), medium (750-2000 µS/cm), high (2000-3000 µS/cm) and very high (>3000 µS/cm) and defined as C-1, C-2, C-3, and C-4 salinity zone respectively. The percent sodium is widely utilized for evaluating the suitability of water quality for irrigation. The Na% is computed concerning relative proportions of cations present in water, where the concentrations of ions are expressed in meq/l, using the following formula:

Na% = Na+K (100)/ (Ca+Mg+Na+K). Wilcox's diagram (Wilcox, 1955) is adopted for the classification of groundwater for irrigation, where EC (salinity) is plotted against Na%. The good waters can be used for irrigation with little danger of harmful levels of exchangeable Na. The moderate waters can be used to irrigate salt-tolerant and semi-tolerant crops under favorable drainage conditions. The bad waters are generally undesirable for irrigation and should not be used on clayey soils of low permeability. Sodium percent values in the analyzed samples (Table 4) vary from 12.55% to 79.63% and the plot of analytical data on the Wilcox diagram (Figure 5) shows that groundwater of the study region is good to permissible quality for irrigation uses in (21% of the samples), doubtful to unsuitable in (67% of the samples) and unsuitable in (12% of the samples).

3-4-4. Sodium Adsorption Ratio (SAR)

The sodium or alkali hazard in the irrigation water is expressed in terms of sodium adsorption ratio ($SAR=Na^{+}/(\sqrt{Ca+Mg})/2)$ and classified into four categories as S1 (SAR<10), S2 (10-18), S3 (18-26) and S4 (>26). The concentration of total soluble salts in irrigation water can be expressed as low (EC<250 µS/cm), medium (250-750 µS/cm), high (750-2250 µS/cm), and very high (>2250 µS/cm) and defined as C_1, C_2, C_3, and C_4 salinity zone respectively. The US Salinity Laboratory's diagram (US Salinity Laboratory Staff, 1954) is used widely for rating irrigation waters. The plot of data on the (USSLS, 1954) diagram, in which the EC is taken as salinity hazard and SAR as alkalinity hazard, (Figure 6) shows that 50% of the water samples are classified within the category of C_3S_1 and C_2S_1 denoting admissible to a good quality of water for irrigation. Good water (C_2S_1) can be used for irrigation with little danger of harmful levels of exchangeable sodium and salinity. The admissible water (C_3S_1) may be used to irrigate salt-tolerant and semi-tolerant crops under favorable drainage conditions.

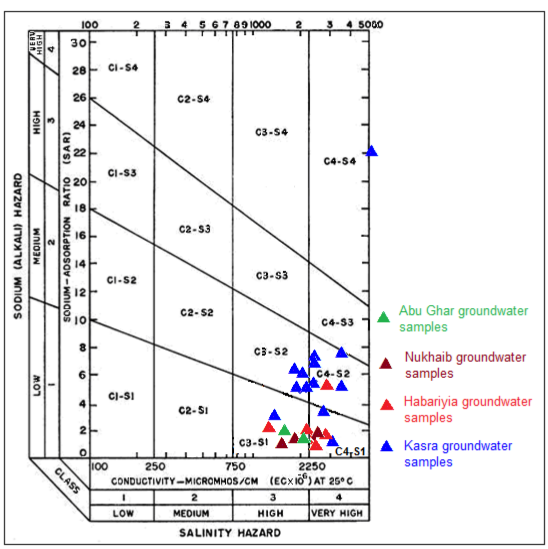

Fig. 5. The plot of Na% and EC×10^{-6} data on Wilcox (1955) diagram

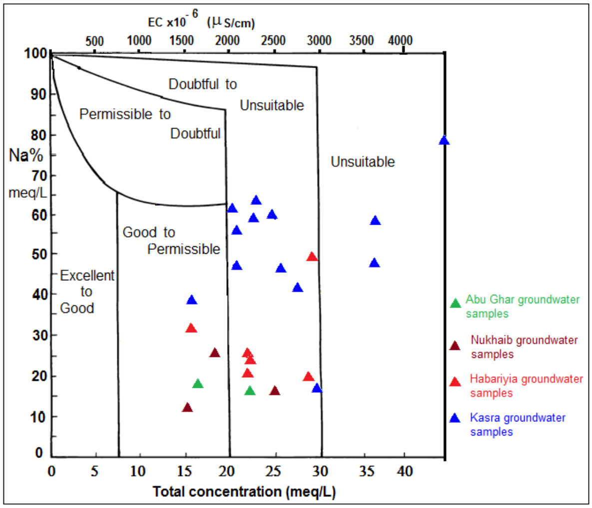

Fig. 6. Plot SAR and ECx10^{-6} data on (USSLS, 1954) diagram

Fifty percent of the total groundwater samples from the aquifer are classified as bad to very bad within the categories of C_4S_1 (21% of the total samples), C_4S_2 (25%) of the total samples), and C_4S_4 (4% of the total samples).

The bad and very bad water with high salinity and medium to high alkalinity are generally undesirable for irrigation and such water should not be used on clayey soils of low permeability

4. Conclusions

Groundwater samples of the aquifer are classified as neutral to slightly alkaline water, slightly saline water, and very hard water according to H_T classification. The groundwater is classified as slightly saturated to supersaturate to the dolomite mineral phase. Saturated indices of gypsum and anhydrite confirm that the groundwater is still active to leach sulfate ions from theb gypsum and anhydrite minerals phase. The concentration of magnesium and calcium are originated from the weathering of carbonate and evaporite rocks (limestone, dolomite, and gypsum). In the majority of the groundwater samples, each borehole sampled had at least one constituent that exceeded the Human drinking-water standard set by World Health Organization, and Maximum Contaminant Levels set by the US Environmental Protection Agency. Concentrations of TDS, H_T, and major ions exceed the desirable limit in most samples and require treatment before its utilization. Suitable water treatment processes such as water softening, ion exchange, and demineralization should be applied to reduce the concentration of ions. The analyzed parameters of the water samples are within the prescribed limits for animal drinking purposes, therefore, the groundwater is potable for use and classified as good to fair class for natural preserve activities.

Quality assessment for irrigation suitability confirms that the groundwater belongs to the moderate class and can be used for irrigation. High values of salinity, residual sodium carbonate, sodium adsorption ratio, and sodium percent at some sites restrict the suitability of groundwater for agricultural purposes and demands special management plans for the area.

Sodium percent values in the groundwater samples and the plot of analytical data on the Wilcox diagram shows that groundwater is good to permissible quality for irrigation uses in (21% of the samples), doubtful to unsuitable in (67% of the samples), and unsuitable in (12% of the samples). SAR values of the groundwater samples and the plot of analytical data on Richard diagram show that 50% of the water samples are classified as admissible to good quality for irrigation. The other fifty percent of water samples are classified as bad to very bad. Water samples were analyzed for chemical properties (inorganic major ions), shows that 25% of pumped water from boreholes is safe against metallic materials and 75% is unsafe.

References

Abd El-Aziz, S.H. (2017). Evaluation of groundwater quality for drinking and irrigation purposes in the north-western area of Libya (Aligeelat). *Environ Earth Sci*, 76, p.147.

Alaizari, H. (2018). Study of groundwater quality in Wadi Almawaheb and Qa' Asawad in Dhamar City (Yemen) its validity for agricultural use. *Journal of Chemical and Pharmaceutical Sciences*, 11(1), p. 40-44.

Al-Azzawi, A. & Dawood, R. (1996). *Report on detailed geological survey in North West of kilo-160, Rutba area*. Geosurv.int.Rep.

Al-Bassam, K., Al-Azzawi, A.M., Dawood, R.M. & Al-Bedaiwi, J.A. (2000). Subsurface study of the pre-Cretaceous regional unconformity in the western desert of Iraq. *Iraqi Geological Journal*, No.33, p.1-25.

Alfji, J.M. & Fathi A.S. (2016). Evaluation of the Shallow Groundwater Unconfined Aquifer of Some Groundwater Wells of Misurata Region for Drinking and Irrigation. *Journal of Marine Sciences and Environmental Sciences*, 2(2), p.1-10.

Ali, M.F. (2017). Evaluation of Hydrogeological Conditions, of the groundwater reservoir west of Samarra by using Data pumping tests in wells Single. *Tikrit Pure Science Journal*. 22(8), p. 137-150.

Al-Mubarak, M. & Amin, R.M. (1983). *Report on the regional geological mapping of the eastern part of the western desert and western part of the southern desert.* geosurv. Internal Report, 3(3), p. 13-80.

Altoviski, M. (1962). *Handbook of Hydrogeology*. Gosgeolitzdat, Moscow, USSR.

Araim, H.I. (1990). Regional Hydrological Map of Iraq. *Scale*, No.1.

Ayers, R. & Westcot, D. (1985). *Water Quality for Agriculture*, FAO Irrigation and Drain, Paper No. 29, Rev 1, Food and Agriculture Organization of the United Nations Rome, 1-109.

Buday,T. & Hack, J. (1980). *Report on geological survey of the western part of the western desert, Iraq*. GeoServer, Int.Rep.

Collin's, A.G. (1975) *Geochemistry of oilfield water*. Development in Petroleum science-1.

Crist, M.A. & Lowry, M.E. (1972). *Groundwater resource of Natrona County Wyoming: A study of the availability and chemical quality of groundwater*. GS Water Supply paper 1897. US. Government printing office, Washington.

Fitts, C. (2002). *Groundwater Science*. Elsevier Science.

Golekar, R., Baride, M. & Patil, S. (20140). Geomedical health hazard due to groundwater quality from Anjani - Jhiri River Basin, Northern Maharashtra, India. *International Research Journal of Earth Sciences*, 2(1), p.1-14.

Hamza, N. (1997). Geomorphological Map of Iraq. *Scale*, No.1. GEOSURV, Baghdad, Iraq.

Hem, J. (1990). *Study and interpretation of the chemical characteristics of natural water*. 3rd. edition. USGS Water Supply.

Hussien, B. (2010). Hydrogeological Condition within Al-Anbar Governorate. *J. of Anbar Univ. for Pure Science*, 4(3), p.97-111.

Hussien, B., Fayyadh, A. & Nafi, N. (2014). *An Integrated Hydrogeological Approach for Aquifers Systems and Groundwater Flow within Nukhaib-Km*.160 Region (West Iraq). J. of Pure Science, University of Anbar**,** Anbar University, College of Science.

Hussien, B.M. & Faiyad, A.S. (2015). Modeling the hydrogeochemical processes and source of ions in the groundwater of aquifers within Kasra-Nukhaib region (West Iraq). *International Journal of Geosciences*, 7, p.1156-1181.

Jassim, S.Z. & Goff, J.C. (2006). *Geology of Iraq, Published by Dolin, Prague & Moravian Museum Brno.* Printed in Zech.

Jassim, S.Z., Karim, S.A., Basi, M., Al Mubarak, M. & Mansour J. (1984). *Final Report of the regional Geological Survey of Iraq*, 2(11), p. 12-22.

Karanth, K.R. (1989). *Groundwater assessment development and management*. Tata McGraw-Hill Publ. Com. Ltd. New Delhi, India.

Kelley, W.P. (1946). *Permissible composition and concentration of irrigation waters.* In: Proc. Amer. Soc. Civil Eng.

Lewen, M.C. & King, N.J. (1971). *Prospect for developing stock water Supplies from wells in Northeastern.* Car field county, Montana. GS Water Supply paper 1999-F, US. Government printing office, Washington.

Matthess, G. (1982). *The properties of groundwater*. Dep. of Environmental Science. John Wiley & Sons. Inc. New York.

Sessakian, V.K. & Mohamed, B.S. (2007). *Stratigraphy of the Iraqi western desert*. IBGM.

Shafer, M., Overdier, J., Hurley, J., Armstrong, D. & Webb, D. (1997). The influence of dissolved organic carbon, suspended particulates, and hydrology on the concentration, partitioning and variability of trace metals in two contrasting watersheds (USA). *Chem. Geol*, No.136, p.71–97.

Shelton, L. (1994). *Field Guide for collecting and processing stream-water samples for the National Water Quality Assessment Program*. USGS Open-File Report 94-455. Sacramento, California. US.Geological Survey. NAWQA Field Technical Support. Placer Hall 6000 J Street Sacramento, Ca. 5819-6129.

US Environmental Protection Agency (2002). *Drinking Water Advisory Consumer Acceptability Advice and Health Effects Analysis on Sodium.* Office of Water, Washington DC.

US Salinity Laboratory Staff (USSLS) (1954). *Diagnosis and improvement of saline and alkali soils*. U.S. Department of Agriculture Hand Book.

Walton, W.C. (1970). *Groundwater Resource Evaluation*. Mc. Graw-Hill series.

WHO (1984). *Guidelines for drinking water quality Recommendation World Health Organization*, Geneva.

WHO (2006). *Guidelines for drinking-water quality*, Vol.1, Recommendations, World Health Organisation, Geneva.

Wilcox, L. (1955). *Classification and use of irrigation waters*, US Department of Agricultural Cir 969, Washington DC.