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Hydrochemical Evaluation for Al-Sada Area Wells and their Suitability for Agricultural Usages

Kotayba T. Al-Youzbakey*, Ali M. Sulaiman.

Dams and Water Resources Researches Center, University of Mosul, Mosul, Iraq.

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ABSTRACT

The present study is concerned with the impact of the geological nature of Al-Fat'ha Formation rock beds and soil on the well water quality of the Al-Sada area (about 2 Km. from the border of Mosul city toward the north). Groundwater passes through different depths dissolving gypsum within their passages between gypsum fractures, which is assumed as the major constituents of Al-Fat'ha Formation. It was found that water resources had significant concentrations of total dissolved solids (TDS), total hardness (TH), calcium (Ca^{2+}), magnesium (Mg^{2+}), sodium (Na^{+}), sulphate (SO_4^{2-}), bicarbonate (HCO_3^-) and chloride (Cl^-).

Cations and anions are ordered as $Na^{+} > Ca^{2+} > Mg^{2+} > K^{+}$ and $SO_4^{2-} > Cl^- > HCO_3^- > NO_3^-$ in shallow wells (1 and 2) and $Ca^{2+} > Mg^{2+} > Na^{+} > K^{+}$ and $SO_4^{2-} > HCO_3^- > Cl^- > NO_3^-$ in deep wells (3, 4 & 5) as well as the well No. 6. The deep wells classified as high salinity water and shallow wells as very high salinity, all wells could be used for plants that bearing salinity with continuous leaching in permeable soils.

1. Introduction

Al-Sada area is located near Mosul city, about 2 Km. from the border of the city toward the north. There are many farms distributed in the area around the road (Mosul – Tel Kaif) (Figure 1). Most farms nearly planting many kinds of trees, as well as vegetables and the people drill many wells in the area for agriculture usage. These wells are varied in the drilling technique and depth. Some wells are about 5-10 m. depth, and the others are more than 30 meters.

The rock layer types in this region belong to Al-Fat'ha Formation, which is known to have repeated cycles. Each cycle consists of gypsum, marl, limestone, and halite [1]. The land in this area comprised of a 0-5m layer of soil. This may contain in some places a high amount of secondary gypsum and halite, as well as the rock fragments of gypsum and carbonates due to weathering in *situ* of the Fat'ha Formation layers.

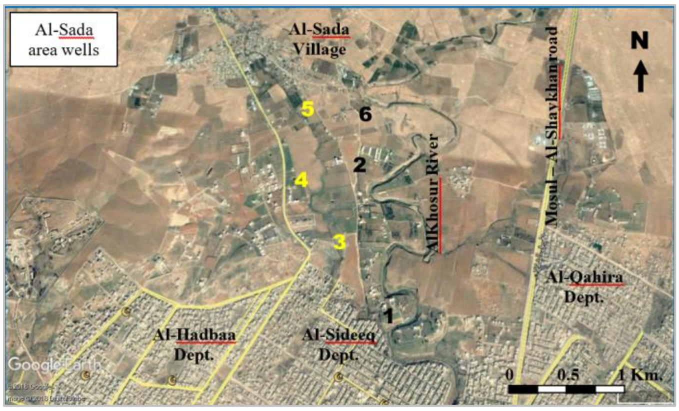

Figure 1: Location map of wells in Al- Sada area.

Groundwater is found almost everywhere beneath the earth's surface not in a single widespread aquifer but in thousands of local aquifer systems and compartments that have similar characters [2]. Knowledge of the occurrence, replenishment, and recovery of groundwater has special significance in arid and semi-arid regions due to discrepancy in monsoonal rainfall, insufficient surface waters, and over-drafting of groundwater resources, [3]. The chemical alteration of rainwater depends on several factors such as soil–water interaction, dissolution of mineral species, and anthropogenic activities [4].

The concentrations of dissolved ions in groundwater samples are generally governed by lithology, nature of geochemical reactions, and solubility of interaction rocks, [5,6].

The groundwater quality is affected by dissolving gypsum. Groundwater takes different passages in the gypsiferous rocks, in the form of channels, fractures, joints, veins, and veinlets. These channels are assumed to be fractures where gypsum had been dissolved. Groundwater is moving in different levels, dissolving gypsum rocks as the main part of the Al-Fat'ha Formation, as well as the fragments of gypsum scattered within the topsoil. It varies among the locations depending upon several factors controlling the groundwater quality like, rocks type, type and amount of the soluble minerals, area of contact between rock and water (porosity), medium temperature, fluid pressure, and flow velocity [2,7]. Calcium carbonate assumed to be the main component of limestone and marl, as well as clay minerals mainly illite, chlorite, and the limited ratio of montmorillonite [8]. These minerals found within Al-Fat'ha Formation are affecting the nature of groundwater quality, due to the dissolving of calcium carbonate [9,10]. High sulfate concentration is known to reduce the activity of aerobic microorganisms, (one of the main producing source of CO_2). Carbonic acid (CO_2 in water) is indirectly responsible for producing bicarbonate by carbonate dissolving, [11].

The present work aims to clarify the impact of aquiver type rocks and the effect of soil and weathered fragments on the chemical nature and quality of the groundwater in Al-Sada wells.

2. Results and Discussions

The chemical composition of groundwater results from the geochemical processes occurring as water reacts with the geologic materials, which it flows. [5].

Dissolving of carbonate, sulfate, and chloride minerals within the aquifer is in general, were a major source of groundwater salinity. The solution of the aquifer matrix is most pronounced with more soluble lithologies, such as carbonate and evaporate [12,13].

2.1. Potential of hydrogen (pH)

All well water show a slight variation in pH values, due to the probable activity of dissolving actions of rocks by groundwater and rock fragments in the upper layer of soils by rainwater precipitation, which are infiltrated to the soil and upper parts of rock layers. Rainwater depends on the carbon dioxide evolving, as well as the other bio-activities by plant roots and microorganisms and dissolving of salt

* **Corresponding Author**
Dams and Water Resources Researches Center, University of Mosul, Mosul, Iraq.
E-mail address: kotaybatawfiq@gmail.com (Kotayba T. Al-Youzbakey).

compounds on the soil surface are influence on the pH of infiltrated water.

All pH values are around pH=7 (Table 1). This declares that the effect of groundwater activity for dissolving is more than the rainwater precipitations.

2.2. Electrical conductivity (EC)

Electrical conductivity reflected the water content of cations and anions. Table (1) shows that the EC values divided into two groups, the first one includes the shallow wells (1, 2 and 6) indicate that there is variance in EC for each well due to the effect of rainwater and the chemical and biochemical activities to dissolved the rock fragments in the upper part of the soil. While the 2nd group which includes the deep wells (3, 4, and 5) have closed values of EC for each well due to the effect of groundwater in rock layers mainly.

2.3. Total Hardness (TH)

Hardness components are affected by the type of rock beds that represent the reservoir or water pass through them[14]. The gypsum/anhydrite bedrocks are the main sources of both Ca^{2+} and SO_4^{2-}, as well as limestone beds (Ca^{2+} and CO_3^{2-}) within Fat'ha Formation are the main constituents of permanent hardness. In addition to the dissolving actions on soil surface compounds (calcareous soil, rock fragments, and secondary salts).

As mention above, TH values are closed for each well in deep kinds, while they varied in shallow wells group.

Table 1: Physical parameters for the water of Al-Sada area wells.

Para-meters	Sampling Date	Shallow Wells No.			Deep Wells No.		
		1	2	6	3	4	5
pH units	Nov. 2013	6.9	6.8	7.2	7.1	6.9	6.8
	Jan. 2014	7.0	6.8	7.6	7.0	7.1	7.0
	Mar. 2014	7.4	7.1		7.4	7.5	7.2
EC µS/cm	Nov. 2013	3140	5510	990	2720	2550	3310
	Jan. 2014	7740	3530	1340	2570	3280	3680
	Mar. 2014	9400	2130		3270	4150	3800
TH mg/l	Nov. 2013	2200	1600	600	1740	2640	2500
	Jan. 2014	1420	1460	880	1680	2000	2300
	Mar. 2014	1500	900		1760	2260	2480
TDS mg/l	Nov. 2013	4100	5740	980	3360	3650	4380
	Jan. 2014	7030	3480	1350	3050	3630	4200
	Mar. 2014	8130	1630		3100	3010	4030

2.4. Total dissolved solids (TDS)

Total dissolved solids represent all unstable minerals under weathering conditions (e.g. gypsum/anhydrite, calcite, dolomite, and secondary minerals) by groundwater and infiltrated water with aquiver and topsoil, respectively.

All TDS values are different for each shallow well according to the role of the infiltration rainwater, mainly, and its variance effect on soil compounds from location to another. While in the deep water wells all the TDS values almost are similar in each well.

In addition to, the variety of TDS and other physical parameters among shallow and deep wells according to the location, topography, soil type, and water infiltration quantities.

2.5. Calcium and Magnesium (Ca^{2+} & Mg^{2+})

Evaporite and Carbonate rocks found within Al-Fat'ha Formation are mainly composed of many minerals which represent the main sources of calcium and magnesium: gypsum ($CaSO_4.2H_2O$), anhydrite ($CaSO_4$) calcite ($CaCO_3$), dolomite (Ca Mg (CO_3)2) and gypsiferous and calcareous cementing materials in bedrocks. As well as, from the weathered rock fragments, some type of clay minerals and secondary minerals like halite and secondary gypsum. All these minerals have the ability to effected by weathering conditions, and dissolved in water, with a pH less than 8 [15, 16]. The figure shows a positive relationship between calcium and sulfates which indicates that the main source of calcium comes from the dissolution of gypsum/ anhydrite (Figure 2). In turn Figure (3) show a random relationship between calcium and carbonate, which represents a secondary effect of dissolving carbonate. The most calcium concentrations in deep well water seem to be around 400 mg/l which are ranged between 264 – 577 mg/l. these closed values are due to the effect of groundwater activities. In the shallow well water, calcium concentrations are different, and in general are less than the above values of deep wells.

The same conditions affect the magnesium concentrations in both shallow and deep wells. Magnesium in wells water has come from the dissolving of marl mainly (Figure 4), as well as dolomite and some kinds of clay minerals found within carbonate rocks. Magnesium in deep wells is around 250 mg/l, while in the shallow wells ranged (23 to 148) mg/l.

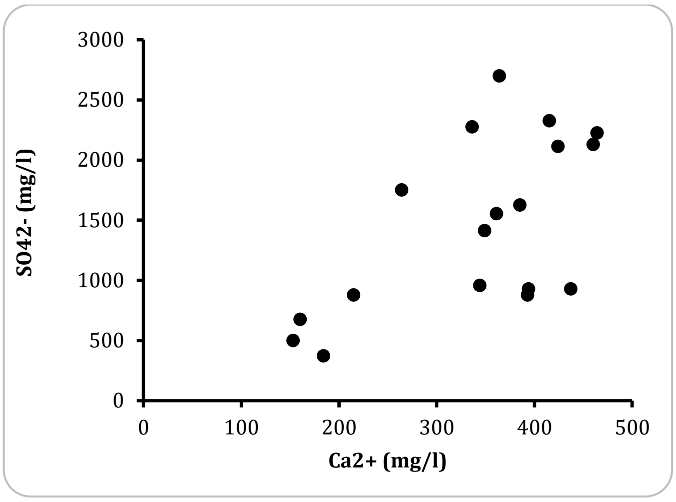

Figure 2: The semi linear relationship between calcium and sulfates in wells water.

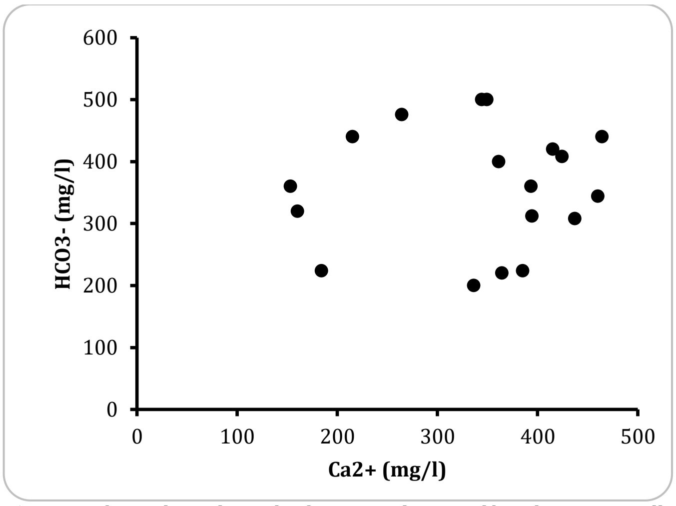

Figure 3: The random relationship between calcium and bicarbonates in wells water.

2.6. Sodium and Potassium (Na^+& K^+)

Sodium and potassium (alkalies cations) are found in halide minerals as halite within Fat'ha Formation layers and as secondary minerals especially at the upper part of the soil. Due to the high solubility of alkalies, most of the secondary minerals are dissolved by the rain precipitation and leaching by surface water to other places of the soil surface. Figure (5) declares that there is a clear relationship

between sodium and chloride which reflects the effect of dissolving halite within Fat'ha Formation and the secondary halite in the upper part of the soil.

In otherwise, potassium may come from some kind of clay minerals, a well as the dissolving of fertilizer compounds. Table (2) and Figure (6) show that there is a random relationship between potassium and nitrate anions, which indicates that the chemical fertilizers (N.P.K.) were not used in the area [9].

In general, sodium founds in high concentrations in all wells. Sodium ranged (60-342) mg/l in deep wells, while it ranged (14-1940) mg/l in shallow wells. This may indicate that the low varieties in the first group due to the dissolving of halite which founds in the rocks of Fat'ha Formation, while the wide-ranged in second group reflect the effect of rain and surface water on dissolving the secondary halite in the upper part of the soil, and it is related to the weather conditions through the year [10].

Potassium found in the well water samples in very low concentrations which were ranged (0.5 – 14) mg/l, this low concentration reflects that potassium comes from clay minerals within marl in Fat'ha Formation or from the secondary halides.

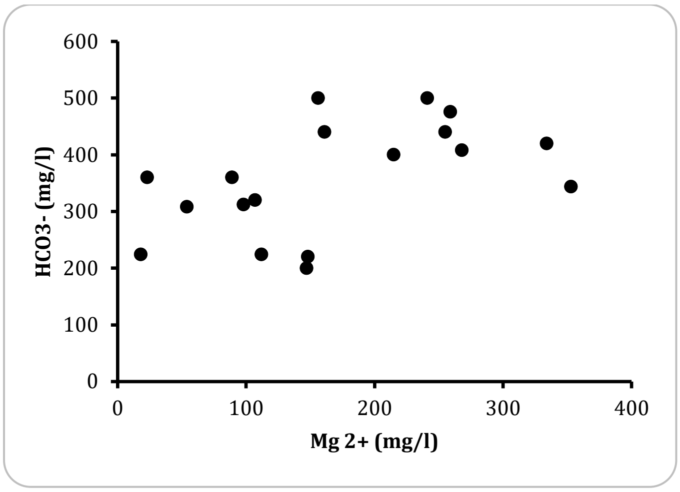

Figure 4: The random relationship between magnesium and bicarbonates in wells water.

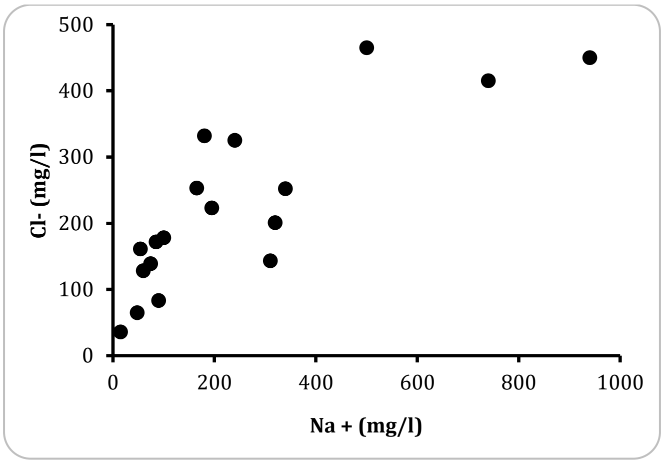

Figure 5: The relationship between sodium and chloride in wells water.

2.7. *Alkalinity (HCO_3^-):*

The alkalinity represents the bicarbonate, which is a product from the solubility of limestone and carbonate cementing material in marl beds within Fat'ha Formation.

In general, alkalinity concentrations in deep wells water (344-511) mg/l were more than shallow wells water (200-360) mg/l. The values of alkalinity in the first group are due to the solubility of limestone layers that alternated with gypsum/anhydrite layers within Fat'ha Formation, which depend on the groundwater activity. In turn, the limestone rock fragments within the upper part of the soil as well as, the subsurface limestone beds were the main sources of alkalinity in shallow wells water, which depend on the infiltration of surface water and rainfall activity.

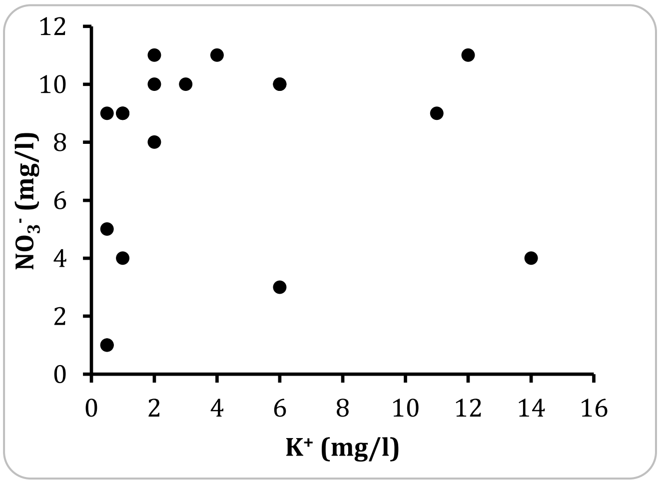

Figure 6: The relationship between potassium and nitrate in wells water.

Table 2: The chemical composition (mg/l) of the studied well's water.

Cations & Anions		Sampling date	Shallow Wells No.			Deep Wells No.		
			1	2	6	3	4	5
Cations	Ca^{2+}	Nov/2013	737	393	120	344	577	449
		Jan/2014	304	385	160	264	415	464
		Mar/2014	336	184		361	424	360
	Mg^{2+}	Nov/2013	54	23	39	156	161	241
		Jan/2014	148	112	107	299	354	255
		Mar/2014	147	98		215	268	353
	Na^+	Nov/2013	180	240	48	103	195	165
		Jan/2014	1940	499	90	310	321	342
		Mar/2014	1704	14		60	85	74
	K^+	Nov/2013	2	2	0.5	0.5	0.5	4
		Jan/2014	6	6	6	1	1	12
		Mar/2014	14	3		1	2	11
Anions	HCO_3^-	Nov/2013	308	360	360	500	440	511
		Jan/2014	220	224	320	476	420	440
		Mar/2014	200	312		401	408	344
	SO_4^{2-}	Nov/2013	928	878	500	957	876	1014
		Jan/2014	2700	1625	675	1750	2325	2425
		Mar/2014	3375	929		2253	2314	2728
	Cl^-	Nov/2013	332	1018	65	178	223	253
		Jan/2014	1470	465	83	143	201	252
		Mar/2014	1415	161		168	172	239
	NO_3^-	Nov/2013	10	11	1	5	9	11
		Jan/2014	10	10	3	4	9	11
		Mar/2014	4	10		9	8	9

2.8. *Sulfate (SO42-)*

Sulfate compound occurrence in water resources in high concentration will affect directly and/or indirectly on the bicarbonate concentration because the sulfur compound inhibits the aerobic microorganism activity to produce carbon dioxide, Hence the carbon dioxide pressure affected on this equilibrium [17]. The equilibrium state between the soluble minerals like carbonate and gypsum control the concentrations of bicarbonates and sulfates in groundwater [15].

Sulfate anions are assumed to have the highest concentrations in these water resources due to the high solubility of gypsum. So there is no difference in sulfate concentrations among wells in all sampling dates. Table (2) shows that there is an increase in sulfate concentrations toward the rainfall months. Figure (7) declare the relationship between sulfate and sodium, which reflect the occurrence of Sodium as halide minerals (halite) within Fat'ha Formation layers.

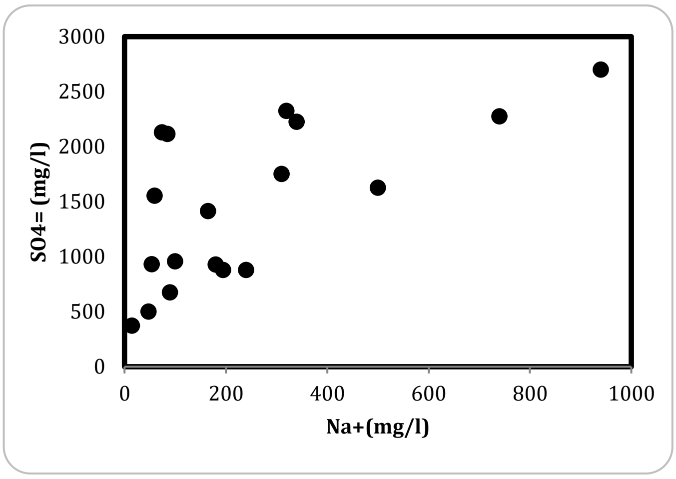

Figure 7: The relationship between sodium and sulfate in wells water.

2.9. *Chloride (Cl^-)*

It is the most dissolving anion in water. It is easily washed from the topsoil by dissolving of secondary salts of halides like halite mainly, by precipitation and surface water runoff. Because of that, its occurrence is limited in soil, due to its infiltration to the groundwater system. Animal urine and solid waste are also the sources for chloride.

Table (2) shows that the concentrations of chloride in deep wells water are ranged from (143-253) mg/l, these values are around 203 mg/l which is mean that chlorides product from the dissolving of halite beds within Fat'ha Formation, and its solubility depending on the groundwater activity. In shallow boreholes water, the concentrations of chloride are in a wide range, they are (332 – 1470) mg/l in well 1, (161 – 1018) mg/l in well 2, and (65 & 83) mg/l in well 3. These ranges reflect the effect of surface water and rainfall activities on the soil surface, which contain different amounts of secondary halite.

2.10. Nitrate (NO_3^-)

This anion is derived from fertilizer, plant decaying, and animal waste. These assume to be the main sources of nitrogen compounds found in soil which directly and/or indirectly ended to the watercourse [18]. As well as, the effect of the atmospheric spark which is the natural source of nitrogen compounds. Nitrogen fixation bacteria found in some plant roots are also responsible for their concentration in the water resources [19].

All water wells sample reflect the low concentration of nitrate anion which were ranged (1-11) mg/l. These low values may be due to the low activity of nitrogen fixation bacteria, and there is no effect of fertilization activities in the area as mention above (Figure 6).

3. Classification and assessment of water quality

Groundwater quality depends on the quality of recharged water, atmospheric precipitation, inland surface water, and on sub-surface geochemical processes [3]. It is important to assess the quality of groundwater in any basin and/or urban area that influences the suitability of water for domestic, irrigation, and industrial needs. Important hydrogeologic factors such as rainfall, mineral weathering, topographic relief, and biological activity in a given basin are important for controlling recharge and hydrogeochemical reactions responsible for chemical constituents contaminating the groundwater [4,6,16].

Table (3) shows the concentration of cations and anions (*epm/l*) of the water of the well. Depending on the electrical conductivity values Wells No. 3,4 and 5 are classified as high salinity and wells No. 1 and 2 as a very high salinity all these wells their waters are unfair for irrigation, only well No.6 is moderate and safe only with permeable soil and moderate leaching, (Richard, 1954) in [20].

The U.S. – Salinity Lab. Classify water depending on their contents of total dissolved solids and electrical conductivity into for classes *C1-C4*, (U.S. – salinity lab. in [21]). According to the T.D.S & E.C. values, the type of water for all wells is classified as *C4* which means that the well waters are used for plants to bear very high salinity water in well porosity soil with continuous washing actions. Except well No. 6 its water quality classified as *C3* which is used for plants to bear salinity with continuous washing.

Table 3: The cations and anions concentrations (*epm/l*) of the water of the studied well.

Sampl. date	Ions	Well No.					
		No.1	No.2	No.3	No.4	No.5	No.6
Nov. 2013	Ca2+	21.85	19.65	17.20	10.75	17.45	7.65
	Mg2+	4.44	1.89	12.84	13.25	19.84	7.33
	Na+	7.83	10.43	4.35	8.48	7.17	2.09
	K+	0.05	0.05	0.01	0.01	0.10	0.01
	∑cations	34.17	32.03	34.40	32.49	44.56	17.07
	HCO3-	5.05	5.90	8.20	7.21	8.20	5.90
	SO42-	19.33	18.29	19.94	18.29	29.46	10.42
	Cl-	9.35	9.15	5.01	6.28	7.13	1.83
	NO3-	0.16	0.18	0.08	0.15	0.18	0.02
	∑anions	33.90	33.53	33.23	31.93	44.96	18.17
Jan. 2014	Ca2+	18.20	19.25	13.20	20.75	23.20	8.00
	Mg2+	12.18	9.22	21.32	27.49	20.99	8.81
	Na+	40.87	21.74	13.48	13.91	14.78	3.91
	K+	0.15	0.15	0.03	0.03	0.31	0.15
	∑cations	71.40	50.36	48.02	62.18	59.28	20.87
	HCO3-	3.61	3.67	7.80	6.89	7.21	5.25
	SO42-	56.25	33.85	36.46	48.44	46.35	14.06
	Cl-	12.68	13.10	4.03	5.66	7.10	2.34
	NO3-	0.16	0.16	0.06	0.15	0.18	0.05
	∑anions	72.69	50.79	48.35	61.13	60.84	21.69
Mar. 2014	Ca2+	32.17	2.35	2.61	3.70	3.22	
	Mg2+	12.10	8.07	17.70	22.06	29.05	
	Na+	32.17	2.35	2.61	3.70	3.22	
	K+	0.36	0.08	0.03	0.05	0.28	
	∑cations	61.43	30.19	38.38	47.00	55.55	
	HCO3-	3.28	5.11	6.56	6.69	5.64	
	SO42-	47.40	19.35	32.35	44.04	44.33	
	Cl-	11.69	4.54	3.61	4.85	3.92	
	NO3-	0.06	0.16	0.15	0.13	0.15	
	∑anions	62.43	29.17	42.66	55.70	54.03	

The RSC values for all wells are below the 1.25 epm/l (Willcox, 1955 classification of irrigation water in [21]). which indicate that there are no hazardous effects of bicarbonate on the quality of water for agricultural purpose due to the high concentration of sulfates (Ca-sulfate) in well waters, [6]).

Tayler (1972) in [21] classified irrigation water into 4 classes; little, moderate, medium, and severe according to their content of chlorides. Wells No. (1 & 2) are classified as class 4 (severe) which could be used for plant bear high chloride contents, these wells are affected by surface water and rainfall activities on dissolving secondary halite in topsoil. Wells No. (3, 4 & 5) are classified as class 3 (medium) which could be used for plant bearing chloride contents. These wells are deep and reflect its content of chlorides within layers of Fat'ha Formation.

U.S. – salinity laboratory classified the irrigation water according to the sharing effect of electrical conductivity (*C*) and sodium adsorption ratio (*S*) into 16 orders as (*C-S*). all well water belongs to the order (*C4-S1*) except well No. (6) is belong order (*C3-S1*). All well waters could be used for plants bearing high salinity with continuous washing processes.

4. Materials and Methods

Six wells were selected in the Al-Sada area (1, 2, 3, 4, 5, and 6) for water quality evaluation. Water samples collected during 17/11/2013, 27/1/2014, and 30/3/2014. water duplicate samples had been collected in clean dry polyethylene bottles for chemical analyses according to standard methods [22]. Some water quality analyses (pH, EC, TH, TDS, Ca^{2+}, Mg^{2+}, Na^+, K^+, HCO_3^-, SO_4^{2-}, Cl^- and NO_3^-) were tested in the laboratory of geochemistry in Dams and Water Resources Researches Center – Mosul University. The turbidity test did not repeat because of the very low turbidity values for all wells water in the first run. The instruments used are pH meter type (PHILIPS, PW 9421), EC - meter type (OGAWA, TOA, CM-205), total hardness, calcium and bicarbonate measured by titration with ethylene diamine tetraacetic acid (EDTA), magnesium was calculated from total hardness and calcium contents. Dry the water sample at 110 ° C to calculate the TDS using an oven. Flame-photometer type (OGAWA, ANA-10KL), used for sodium and potassium determinations. Sulfates were estimated using the colorimetric technique. chloride were analyzed by volumetric methods. Spectrophotometer type (OGAWA, OSK 7724), for nitrate determination. As well as, electronic balance type (Mettler H54 AR) were used.

Ions were converted from milligram per liter to milliequivalent per liter, and anions balanced against cations as a control check of the reliability of the analyses results, (Table 3).

SAR can indicate the degree to which irrigation water tends to enter into cation-exchange reactions in the soil. Sodium replacing adsorbed calcium and magnesium is a hazard as it causes damage to the soil structure and becomes compact and impervious [5].

$$SAR = Na \div \sqrt{(Ca + Mg)/2} \qquad \textit{(all concentrations are in epm)}$$

Residual sodium carbonate (RSC) has been calculated to determine the hazardous effect of carbonate and bicarbonate on the quality of water for agricultural purposes and has been determined by the Equation: [5]

$$RSC = (CO3 + HCO3) - (Ca + Mg) \qquad \textit{(all concentrations are in epm)}$$

5. Conclusion

Low porosity of gypsiferous marl retarded the channeling of water passage through the rocks. This phenomenon shows the differences between positions and sources of water, depth, quantity, and ion concentrations. It reflects its properties, characteristics, and uses.

Precipitation mainly through storms is collecting water in the wades running off the topsoil. Water quality in these wades is extremely affected by soil types and salinity. Sodium and chloride are the most probable ions due to their high dissolving ability, in addition to calcium, magnesium, and other elements.

Due to the chemical properties of all wells water, they are classified saline to high saline water. Moreover, the irrigation activities need experience in selecting plants that bear salinity, well leaching works, and permeable soils.

References

[1] S. Q. Al-Naqib, T. A. Aghwan.Sedimentological Study of the Clastic Units of the Lower Fars Formation. *Iraqi Geol. J.*, **1993**, *26*, 108–121, 1993.

[2] K. E. Leizou,J. O. Nduka, A. W. Verla. Evaluation of Water Quality Index of the Brass River, Bayelsa State, South-South, Nigeria. *Int. J. Res. - Granthaalayah*, **2017**, *5*, 277–287. doi: 10.5281/zenodo.894650.

[3] M. Vasanthavigar, *et al.*, Application of water quality index for groundwater quality assessment: Thirumanimuttar sub-basin, Tamilnadu, India.*Environ. Monit. Assess.*, **2010,** 171, 595–609. doi: 10.1007/s10661-009-1302-1.

[4] J. Raju, U. K. Shukla, P. Ram. Hydrogeochemistry for the assessment of groundwater quality in Varanasi: A fast-urbanizing center in Uttar Pradesh, India. *Environ. Monit. Assess.*, **2011**, *173*, 279–300,.doi: 10.1007/s10661-010-1387-6.

[5] N. Aghazadeh A. A. Mogaddam. Assessment of Groundwater Quality and its Suitability for Drinking and Agricultural Uses in the Oshnavieh Area, Northwest of Iran. *J. Environ. Prot. (Irvine,. Calif).*, **2010**, *01*, 30–40. doi: 10.4236/jep.2010.11005.

[6] B. B. Kapoor, F. Inam, S. S. Deo NAssessment of Physico-Chemical Quality of Ground Water in Some Rural Areas Receiving Industrial Wastewater Discharges in Nagpur District, Maharashtra State, India.o Title. *TIJST*, 2016, *4*, 149–155.

[7] J. A. TothA Conceptual model of the groundwater regime and the hydrogeologic environment *J. Hydrol.*, **1970**, 164–167.

[8] Mustafa, A. M., “Sedimentological studies of the Lower Fars Formation in Sinjar basin, Iraq,” Mosul, 1980.

[9] K. T. Al-Youzbakey, Y. F. Eclimes. Hydrological and Hydrogeochemical Study for Alqoush Plain (Northern Iraq) to Protect Region from the Drought,” in *The 9th Periodical Scientific Conference for Dams and Water Resources Research Center, 28-29 Nov.* **2018**, *2018*, 165–176.

[10] K. T. Al-Youzbakey, A. M. Sulaiman, D. A. Ismaeel The Evaluation of Chemical Characterization for Selected Wells Water in Mosul – Bahshiqa – Shalalat Area, Ninivah Governorate, Northern Iraq,” in *The 9th Periodical Scientific Conference for Dams and Water Resources Research Center, 28-29 Nov.* **2018**, *2018*, 201–216.

[11] C. N. Sawyer. P. L. McCarty. *Chemistry for Environmental Engineering*, 3rd editio. McGraw-Hill Book Company, **1978**.

[12] Wagner, W., *Groundwater in Arab Middle East*. Berlin: Springer-Verlag, 2011.

[13] R. Brassington. *Field hydrogeoloy*, 4th ed. Hoboken, USA: John Wiley & Sons Ltd, **2017**.

[14] D. K. Todd.*Ground Water Hydrology*, 2nd Editio. New York: John Wiley & Sons, **1980**.

[15] F. H. Chappelle. Geochemistry of Groundwater. *TREATISE on GEOCHEMISTRY*, First edit., H. D. Holland and K. K. Turekian, Eds. Elsevier Pregamon, **2004**, 425–449.

[16] R. Gupta,A. K. Misra. Groundwater quality analysis of quaternary aquifers in Jhajjar District, Haryana, India: Focus on groundwater fluoride and health implications. *Alexandria Eng. J.*, **2018**, *57*, 375–381. doi: 10.1016/j.aej.2016.08.031.

[17] F. M. Phillips, M. C. CastroGroundwater Dating and Residence-time Measurements,” in *TREATISE on GEOCHEMISTRY*, First edit., H. D. Holland and K. K. Turekian, Eds. Elsevier Pregamon, **2004**, 451–497.

[18] W. H. Organization, Guidelines for drinking water quality, health criteria and other supporting information Alexandria, Egypt, **1989**.

[19] D. Deming. *Introduction to Hydrogeology*. McGraw-Hill Company, **2002**.

[20] G. I. Obiefuna,A. Sheriff. Assessment of Shallow Ground Water Quality of Pindiga Gombe Area , Yola Area , NE , Nigeria for Irrigation and Domestic Purposes. *Res. J. Environ. Earth Sci.*, **2011**, *3*, 131–141.

[21] S. A. AbawiM. S. Hassan. *The Practice Engineering for Environment. Water Analysis.* Dar Al-Hekma for Publishing, University of Mosul, **1990.**

[22] J. Brandi,L. Wilson-Wilde. *Standard Methods*. **2013**.