HYDROCHEMICAL ASSESMENT OF WATER RESOURCES IN THE SOUTHERN PART OF AL-RAZZAZAH LAKE AND SURROUNDINGS, KARBALA AREA, CENTRAL IRAQ

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ABSTRACT

Nine water samples from eight different resources were collected from the southern part of Al-Razzazah Lake and the adjacent area, which is located West of Karbala city. It has been found that the lake water is characterized by high content of T.D.S., while that near the shore has suffered dilution by the irrigation drainage water and the wells water is mixed with the domestic wastewater of Karbala city via Karbala northern drainage, which is much lower in T.D.S.. The samples R0, R1, R2, R3, R4 and R5 are considered very hard but still can be used for irrigation but care should be taken to sensitive crops. R6 and R7 can be also used for irrigation but gypsum should be added to the soil, moreover this water can be used for non-sensitive crops. The lake water (R8) is not suitable for irrigation as it may cause severe damage to the soil and plants. Sand washing slightly contributes in increasing the Mg^{2+} concentration and alkalinity in the pumped well water used in washing the sand, which changes the water type from $Na^{+} + Ca^{2+}$ to $Na^{+} + Mg^{2+} + Ca^{2+}$. The near shore water sample were found to be of very low concentration compared with those from the interior of the lake, indicating that the Northern Karbala Drainage water pumped to the lake and the spring water are slightly mixed with the lake water due to the difference in densities.

التقييم الهيدروكيميائي لمصادر المياه في الجزء الجنوبي من بحيرة الرزازة والمناطق المجاورة لها, منطقة كربلاء, وسط العراق

رافع زائر جاسم و عقيل عباس الزبيدي

المستخلص

أفضت دراسة تسعة نماذج من المياه جمعت من مصادر مختلفة من الجزء الجنوبي لبحيرة الرزازة والمناطق المجاورة لها غرب مدينة كربلاء، إلى أن مياه البحيرة تتصف بملوحتها العالية بينما تلك التي تكون قريبة من الساحل الجنوبي تكون ذات ملوحة أقل بكثير وذلك لاختلاطها بمياه البزل الزراعي المختلطة مع مياه التصريف الصحي لمدينة كربلاء عبر مبزل كربلاء الشمالي, إضافة إلى تصريف مياه العيون والمياه الجوفية إليها لانخفاض مستوى الماء في البحيرة كثيراً. أظهرت الدراسة أن المياه داخل البحيرة وينابيع شثاثة وقطارة الإمام علي والآبار القريبة من البحيرة إضافة إلى مياه البزل الزراعي المختلطة بمياه التصريف الصحي, هي ذات ملوحة عالية إلا إنه لازال بالإمكان استخدامها لأغراض الزراعة على أن يراعى إضافة الجبس إلى التربة التي تستخدم معها هذه المياه, كما إنه يمكن استخدامها في زراعة المحاصيل غير الحساسة للملوحة. وقد تبين أن وجود مياه داخل البحيرة يمكن أن يؤدي إلى أضرار كبيرة للتربة في حال استخدامها للري. كما أن غسل الرمال المستخرجة من المقالع القريبة بمياه الآبار يؤدي الى إغناء هذه المياه بالمغنيسيوم مما يؤدي الى تغيير هذه المياه من نوع $Ca^{2+} + Na^{+}$ إلى $Ca^{2+} + Mg^{2+} + Na^{+}$. كما بينت الدراسة أن تركيز مياه البحيرة المنمذجة قرب الساحل أقل بكثير من تلك التي نمذجت من داخل البحيرة مما يشير الى أن هذه المياه هي التي يتم ضخها من مبزل كربلاء الشمالي وقد اختلطت بشكل قليل جداً مع مياه البحيرة إلا أن اختلاطها بطيء بسبب اختلاف الكثافات.

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INTRODUCTION

Al-Razzazah Lake is located West of Karbala, central Iraq, The semi arid climate together with the shortage and even no supply of water to the lake from Al-Habaniya Lake, beside the scarcity of rain and dryness of the springs are the main reasons for the decrease in water storage of the lake, which, led to a considerable change in the lake water quality bringing about death to the living organisms at the lake shore (Figs.1 and 2). Therefore, human dependence on water supply in the area is based on two sources, which are; the ground water from springs and drilled wells, the agricultural drainage and domestic wastewater and the water pumped by pipelines from Euphrates River to the area for drinking and domestic purposes. Therefore, hydrochemical assessment for these water sources was applied in this study.

Hydrochemical study is one of the most important ways to assess the water quality and its suitability for different aspects of life. The major cations and anions usually used in the hydrochemical studies are: Ca^{2+}, Mg^{2+}, Na^{+}, K^{+}, Cl^{-}, HCO_3^{-} and $SO_4^{=}$. They play a significant role in water quality assessment and classification (Todd, 1980 and Davis, and Dewiest, 1966). Many types of ionic relations could be used, they are a combination of two or group or all the ions (Sadashivaiah *et al*., 2008 and Khodapanah *et al*., 2009). In such studies the sodium percent, magnesium hazard and SAR are used to indicate the ionic effect of the chemical elements of water on the physical properties of soil, also the suitability of water for irrigation and other aspects of water need. Chemical classification using Piper's diagram (1944) and Back and Hanshaw (1972) also throws light on the concentration of the dominant cations and anions and their interrelationships (Zaporozee, 1972).

The objective of the present work is to study the major ions chemistry of the water sources in the southern part of Al-Razzazah Lake and its vicinity and to assess its quality and reliability for human consumption and irrigation.

a: The dead fish close to the land

b: Shells of dead organisms closer to the water

Fig.1: Effect of shoreline retreat and T.D.S. increase on the living organisms in Al-Razzazah Lake

Fig.2: Effect of water supply shortage on the lake storage

The study area is located West of Karbala City, between 32° 15' and 32° 45' North and 43° 25' and 44° 00' East (Fig.3). The area is characterized by a semi-arid environment of hot dry summer, cold dry winter with annual rainfall (109 – 122 mm) mainly during January to April and annual evaporation (3194.3 – 3332.7 mm) (Table 1) (IGOMI, 2000).

Table1: Climatic Information at Karbala and Najaf stations

Station	Temp. Max. (°C)	Temp. Min. (°C)	Annual rainfall (mm)	Annual evaporation (mm)
Karbala	43	6.4	109	3332.7
Najaf	44	6.4	122	3194.3

- **Previous Works**

Al-Razzazah Lake and the adjacent area have been studied by Parsons (1955) to provide the hydrogeological information for the Western Desert. Ingra (1974) investigated the area hydrologically by drilling many boreholes to provide the relevant information for hydrogeological assessment. Idrotechnico (1977) carried out a hydrogeological study for sector No.4, which includes the study area, by drilling many boreholes. Al-Basrawi (1996) studied the hydrogeology of Al-Razzazah Lake and the adjacent area, in which he studied the variation in quality for the surface water and groundwater enters the lake. Al-Basrawi (2005) conducted a hydrogeological and hydrochemical evaluation for Karbala Governorate.

- **Geology**

Al-Razzazah Lake is surrounded by Tertiary sediments of different ages and types. They are Dammam, Euphrates, Nfayil, Injana and Dibdibba formations. Quaternary sediments cover vast area of the lake vicinity represented by gypcrete, inland sabkha, depression fill, flood plain and aeolian sediments (Fig.3).

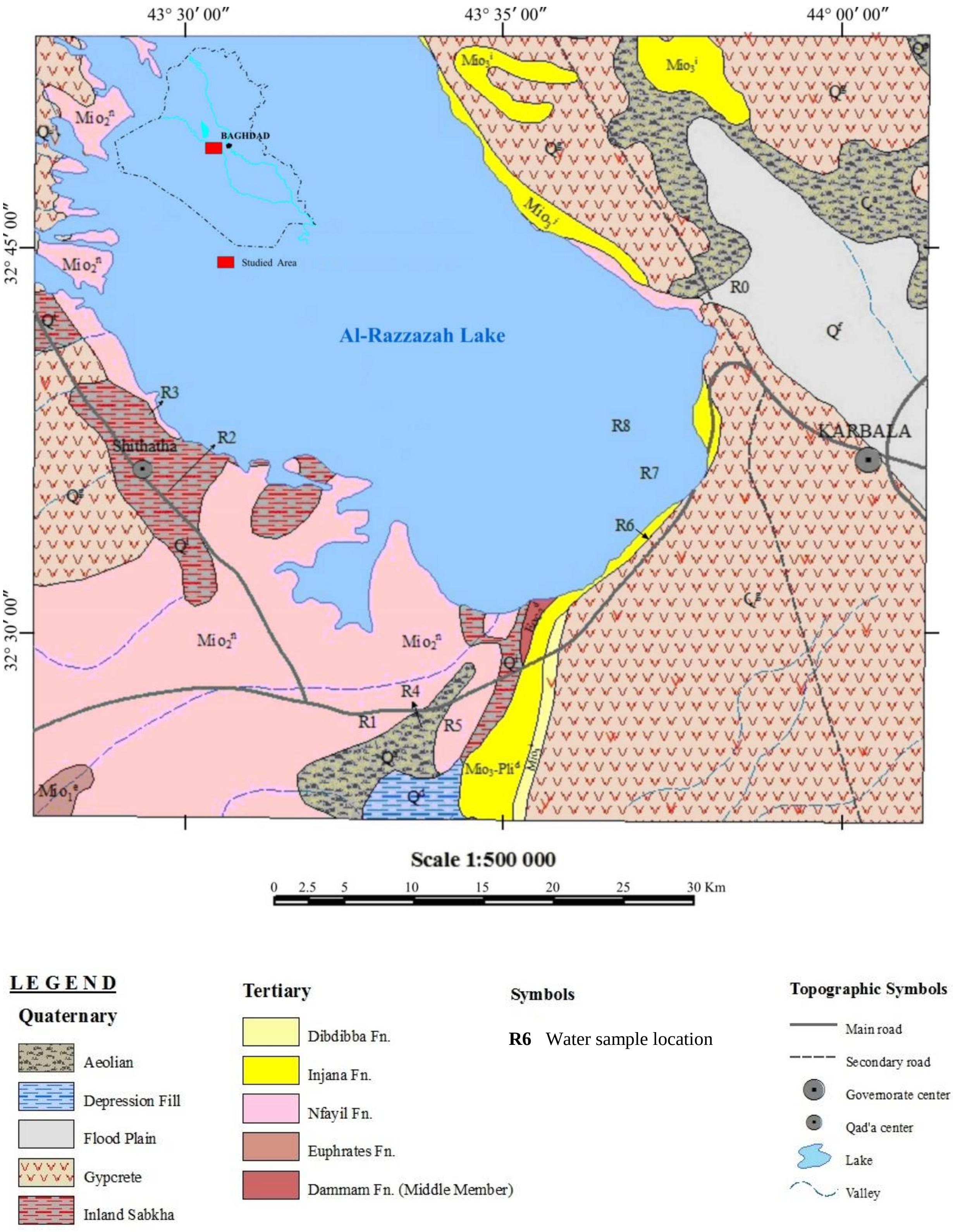

Fig.3: Location and geology of the study area and water samples sites
(after Sissakian, 2000)

METHODOLOGY

▪ Sampling

Nine samples were collected from the area during 21 August 2010 (Figs.3, 4, 5 and 6). Two of them were from Al-Razzazah Lake, one near shoreline (R7) and the other was from about 100 m away inside the lake (R8). One sample from Northern Karbala Drainage includes mixed agricultural, industrial and domestic wastewater from Karbala area and open into Al-Razzazah Lake (R0). Spring waters are represented by two samples, one from a sulfuric water spring (R1) and the other belongs to the so-called Qatarat Al-Immam Ali (R6). One sample from spring waters used for irrigation (R2) related to drilled wells. Well waters were also collected, one from north of Shithatha (R3) and the other is used for washing sands quarried from Al-Ukhaider area (R4). Another water sample was collected after washing the sand (R5) to study the change in water quality after sand washing.

▪ Analysis

Chemical analyses of the water samples were carried out in the laboratories of the State Association of Ground Water following the standard procedures recommended by APHA (1994). The collected samples were analyzed for Na^+, K^+ by ELICO Flame Photometer; for NO_3^- by CROMTIC Spectrophotometer; for Ca^{2+}, Mg^{2+}, HCO_3^-, Cl^-, $SO_4^=$ by titration and T.D.S. by heating and evaporation. While, pH and EC were measured in the laboratory by WTW portable equipment. The chemical analyses are listed in Table (2).

RESULTS AND DISCUSSION

▪ Water Quality Assessment

The main purpose for hydrochemical analysis is to conclude the water quality extracted from the chemical analysis and field measurements (Table 2). The calculated relationships include the percent sodium (Na%) total hardness (TH), magnesium hazard (MH) and sodium adsorption ratio (SAR).

Water types were extracted from the water formula (Table 3), indicating T.D.S., anions (epm%) 15% in decreasing order, cations (epm%) 15% in decreasing order and pH.

Therefore, application of hydrochemical assessment is to conclude the water suitability for different uses based on different chemical indices.

The water formula for the studied samples shown below, shows that all the samples are of Sulphate – Chloride type, except R0 and R6 are of Chloride – Sulphate type, and all the samples are of Sodium – Calcium except for R8, which is of Sodium – Calcium – Magnesium type. pH of all the samples are alkaline, ranging between 7.14 and 8.3. Their T.D.S. ranging between (1503 – 3246) ppm, except sample No.R8, where it’s T.D.S. is 29956 ppm.

a: Location of near shore lake water sample (R7)

b: Location of off shore lake water sample (R8)

c: Agricultural drainage and domestic wastewater (R0) (Northern Karbala Drainage)

Fig.4: Location sites of lake and North Karbala Drainage water samples

a: Well water before using for sand washing (R4)

b: After sand washing process (R5)

c: Well water

Fig.5: Location sites of well water samples

a: Spring water (R1)

b: Irrigation water from springs (R2)

c: Site of Qatarat Al-Immam Ali

d: Qatarat Al-Immam Ali spring water (R6)

Fig.6: Location sites of spring water samples

Table 2: Chemical analysis of water samples collected from the southern part of Al-Razzazah Lake and its vicinity

a: cations, pH, EC and T.D.S.

S. No.	pH	EC (micro mohs/cm)	T.D.S. (ppm)	Ca^{2+}			Mg^{2+}			Na^{+}			K^{+}		
				(ppm)	(epm)	(epm%)	(ppm)	(epm)	(epm%)	(ppm)	(epm)	(epm%)	(ppm)	(epm)	(epm%)
R0	8.01	2740	1889	194	9.7	39.64	56	4.59	18.76	232	10.08	41.2	4.1	0.10	0.4
R1	7.31	2210	1553	128	6.4	27.19	46	3.77	16.01	303	13.17	55.95	8.2	0.20	0.85
R2	8	2170	1518	131	6.55	27.17	49	4.01	16.63	308	13.39	55.54	6.3	0.16	0.66
R3	7.24	2160	1503	148	7.4	33.39	37	3.03	13.67	267	11.60	52.35	5.3	0.13	0.59
R4	7.14	2230	1871	126	6.3	31.05	38	3.11	10.72	247	10.73	52.88	6.1	0.15	0.75
R5	8.03	2370	1672	134	6.7	25.75	86.1	7.05	27.08	281	12.21	46.91	3	0.07	0.26
R6	8.3	4790	3246	213	10.65	24.73	118	9.67	22.46	519	22.56	52.39	7.1	0.18	0.42
R7	8.11	4280	2917	213	10.65	25.75	95	7.78	18.82	525	22.82	55.19	4.3	0.10	0.24
R8	7.9	42900	29956	2009	100.45	28.61	1145	93.85	26.72	2600	113.04	32.19	1714	43.83	12.48

b: anions

S. No.	Cl^{-}			NO_3^{-}			$SO_4^{=}$			HCO_3^{-}			$CO_3^{=}$		
	(ppm)	(epm)	(epm%)	(ppm)	(epm)	(epm%)	(ppm)	(epm)	(epm%)	(ppm)	(epm)	(epm%)	(ppm)	(epm)	(epm%)
R0	380	10.70	41.42	2.3	0.03	0.12	486	10.12	39.18	304	4.98	19.28	0	0	0
R1	332	9.35	40.44	4.1	0.06	0.26	508	10.58	45.76	191	3.13	13.54	0	0	0
R2	329	9.26	40.09	4.5	0.07	0.30	513	10.68	46.23	189	3.09	13.38	0	0	0
R3	291	8.19	37.93	2.3	0.03	0.14	563	11.72	54.29	101	1.65	7.64	0	0	0
R4	289	8.14	40.35	3.4	0.05	0.25	479	9.97	49.43	123	2.01	9.97	0	0	0
R5	290	8.16	32.83	3	0.04	0.16	585	12.18	49.02	273	4.47	17.99	0	0	0
R6	675	19.01	44.90	22	0.35	8.3	814	16.95	40.03	368	6.03	14.24	0	0	0
R7	498	14.02	35.16	3.4	0.05	0.13	989	20.60	51.65	318	5.21	13.06	0	0	0
R8	4610	129.85	37.79	40	0.64	0.19	9270	193.12	56.2	1221	20.01	5.82	0	0	0

Table 3: Chemical formulas for the collected samples according to Ivanov equation (in Ivanov *et al*., 1998)

R0	1889 (ppm)	$\frac{Cl^{-}\,(40.42)\ SO_4^{=}\,(39.18)\ HCO_3^{-}\,(19.28)}{Na^{+}\,(41.2)\ Ca^{2+}\,(39.64)\ Mg^{2+}\,(18.76)}$	8.01
R1	1553 (ppm)	$\frac{SO_4^{=}\,(45.76)\ Cl^{-}\,(40.44)}{Na^{+}\,(55.95)\ Ca^{2+}\,(27.19)\ Mg^{2+}\,(16.01)}$	7.31
R2	1518 (ppm)	$\frac{SO_4^{=}\,(46.23)\ Cl^{-}\,(40.09)}{Na^{+}\,(55.54)\ Ca^{2+}\,(27.17)\ Mg^{2+}\,(16.63)}$	8
R3	1503 (ppm)	$\frac{SO_4^{=}\,(54.29)\ Cl^{-}\,(37.39)}{Na^{+}\,(52.35)\ Ca^{2+}\,(33.39)}$	7.24
R4	1871 (ppm)	$\frac{SO_4^{=}\,(49.43)\ Cl^{-}\,(40.35)}{Na^{+}\,(52.88)\ Ca^{2+}\,(31.05)}$	7.1
R5	1672 (ppm)	$\frac{SO_4^{=}\,(49.02)\ Cl^{-}\,(32.83)\ HCO_3^{-}\,(17.99)}{Na^{+}\,(46.91)\ Mg^{2+}\,(27.08)\ Ca^{2+}\,(25.75)}$	8.03
R6	3246 (ppm)	$\frac{Cl^{-}\,(44.90)\ SO_4^{=}\,(40.03)}{Na^{+}\,(52.39)\ Ca^{2+}\,(24.73)\ Mg^{2+}\,(22.46)}$	8.3
R7	2917 (ppm)	$\frac{SO_4^{=}\,(51.65)\ Cl^{-}\,(35.16)}{Na^{+}\,(55.19)\ Ca^{2+}\,(25.75)\ Mg^{2+}\,(18.82)}$	8.11
R8	29956 (ppm)	$\frac{SO_4^{=}\,(56.2)\ Cl^{-}\,(37.79)}{Na^{+}\,(37.79)\ Ca^{2+}\,(28.61)\ Mg^{2+}\,(26.72)}$	7.9

For hydrochemical facies and characterization of the studied water samples, Piper's trilinear diagram (1944) and the subdivisions of Back and Hanshaw (1972) were adopted (Fig.7).

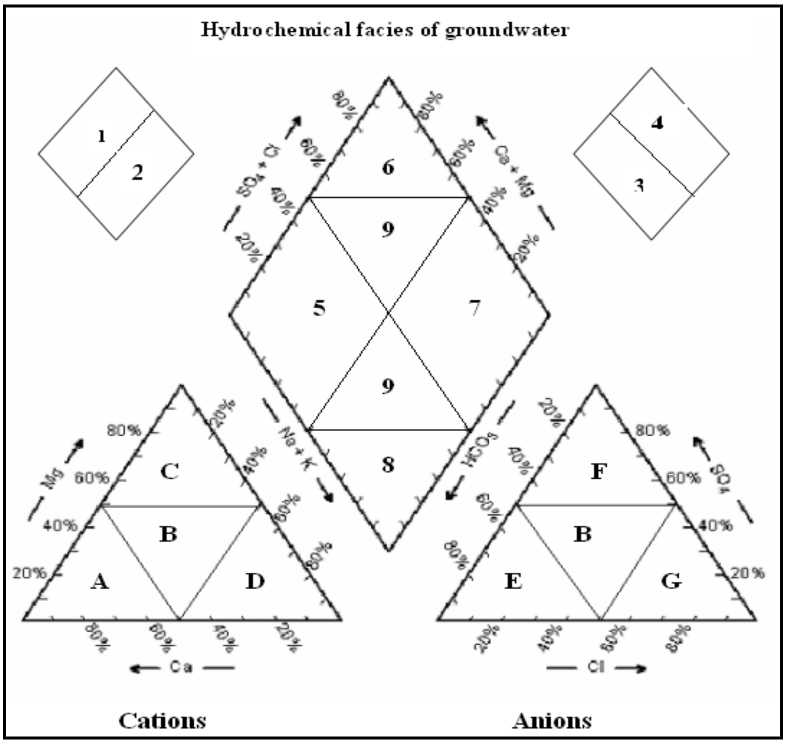

Fig.7: Piper's trilinear diagram (1944) and the subdivisions of Back and Hanshaw (1972)

The Plot of the studied water samples on the Piper's diagram (1944) are shown in Figure (8).

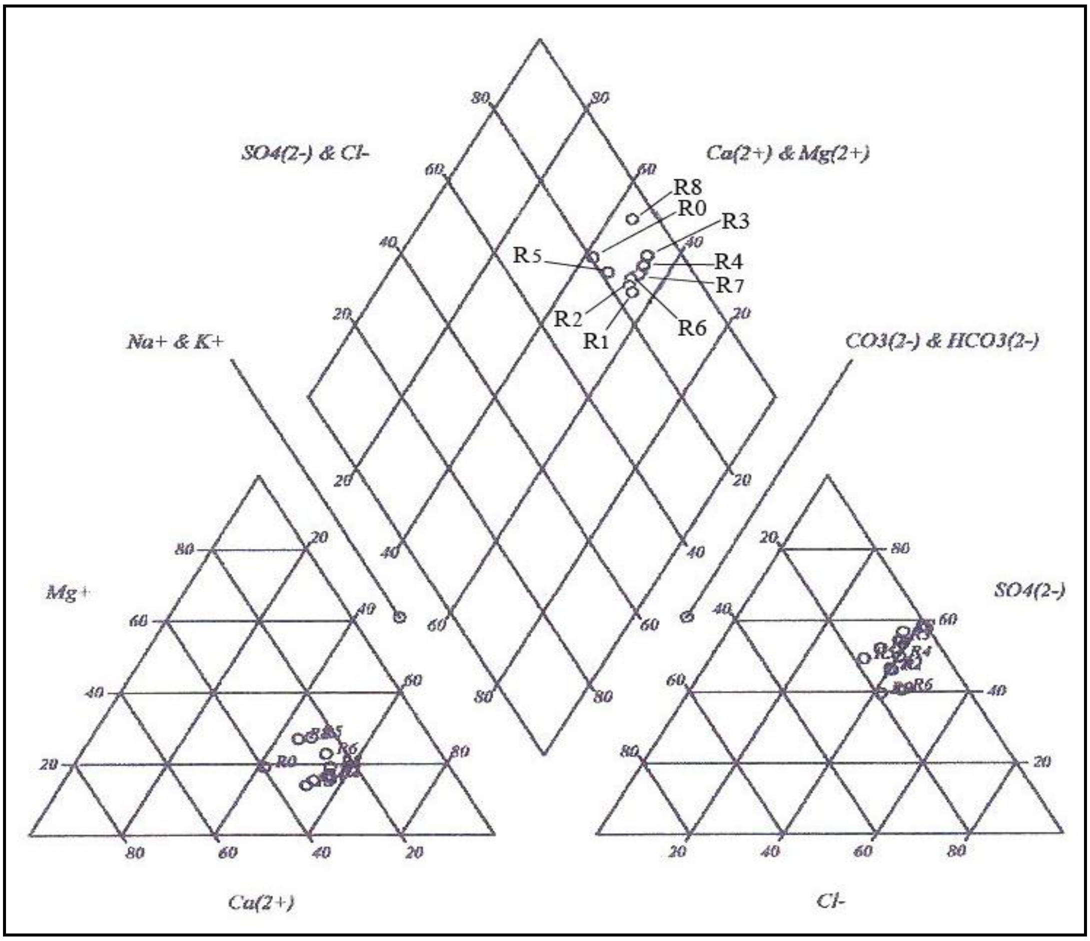

Fig.8: Water samples plot on Piper's trilinear diagram

The application of Back and Hanshaw (1972) subdivisions on Piper's diagram (1944) shows that:
– All the samples have (HCO_3^- + $CO_3^=$) < (Cl^- + $SO_4^=$)
– R1, R2, R3, R4, R6 and R7 have non carbonate salinity (primary salinity) > 50 %
– R0 and R5 have no dominant cation – anion pair
– R8 has non carbonate hardness (secondary salinity) > 50%

─ Water samples suitability for drinking: Since all the water samples were collected from the water sources at the southern part of Al-Razzazah Lake and its vicinity (including the water of Qatarat Al-Immam Ali (which people used to drink for blessing) have a Total Hardness value > 300 (Table 4), therefore they are considered very hard according to Todd's classification (1980) and therefore can't be used for drinking (Table 5).

Table 4: Total Hardness calculated from the chemical analysis of the water samples

	R0	R1	R2	R3	R4	R5	R6	R7	R8
TH (ppm)	715	509	528	522	471	688	1020	922	9720

Table 5: Classification of water based on hardness (after Sawyer and McCarthy, 1967)

Total Hardness (as $CaCO_3$)	Water type	Studied water samples
0 – 75	soft	none
75 – 150	moderate	none
150 – 300	hard	none
> 300	very hard	R0, R1, R2, R3, R4, R5, R6, R7, R8

Based on Crist and Lowry (1972) limits of T.D.S. concentrations in water for animals drinking, it is found that only R0, R1, R2, R3, R4, R5 can be used for chickens drinking, while all the water sources in this study (except R8) can be used for horses drinking, milk caws, meat caws and sheep drinking (Table 6).

Table 6: Water usage for animals drinking according to Crist and Lowry (1972)

Animal	T.D.S. (mg/l)	Studied samples	Remarks
chickens	2860	R0, R1, R2, R3, R4, R5	R8 could not be used for drinking for any type of animals
horses	6435	R0, R1, R2, R3, R4, R5, R6, R7	
milk caws	7150	R0, R1, R2, R3, R4, R5, R6, R7	
meat caws	10000	R0, R1, R2, R3, R4, R5, R6, R7	
sheep	12900	R0, R1, R2, R3, R4, R5, R6, R7	

– **Suitability for irrigation:** To study the possibility of using these water sources for irrigation, Na% were calculated according to the equation No.1 (Table 7), and Wilcox (1955) classification was adopted (Table 8).

$$Na\% = \frac{(Na^{+} + K^{+})\,100}{Ca^{2+} + Mg^{2+} + K^{+}} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (1)$$

All ionic concentrations are expressed in milliequivalents per liter.

Table 7: Calculated Na% for the studied samples

	R0	R1	R2	R3	R4	R5	R6	R7	R8
Na%	20.8	56.79	56.2	52.93	53.62	47.17	47.28	55.42	44.67

Table 8: Water types according to Percent Sodium according to Wilcox (1955)

Na%	Water type	Studied water samples
< 20	excellent	none
20 – 40	good	R0
40 – 60	permissible	R1, R2, R3, R4, R5, R6, R7, R8
60 – 80	doubtful	none
> 80	unsuitable	none

According to the Na%, it has been found that the agricultural drainage and domestic wastewater sample R0 are was classified as good for irrigation, while R1, R2, R3, R4, R5, R7 and R8 are permissible (since the water discharge of R6 is very low, it has been excluded from this assessment).

Due to the fact that saline water will produce an alkali soil and irrigation with Na^+ enriched water results in ion exchange reactions such as uptake of Na^+, release of Ca^{2+} and Mg^{2+}, this causes soil aggregates to disperse and reduces its permeability. Therefore, the tendency of sodium to increase its proportion on the cation exchange sites at the expense of other types of cations (primarily calcium and magnesium) is estimated by the sodium adsorption ratio (SAR), this ratio has been used widely in the assessment of surface and groundwater (Miller and Gardiner, 2007; Tijani, 1994; Khodapanah, 2009 and Sadashivaiah *et al*., 2008). The Sodium Adsorption Ratio is calculated according to the equation No.2 (Table 9), and the usage of the different water types included in this study for irrigation are mentioned in Table (10):

$$SAR = \frac{Na^+}{\sqrt{\frac{Ca^{2+} + Mg^{2+}}{2}}} \quad \ldots\ldots\ldots\ldots\ldots\ldots \quad (2)$$

Table 9: Calculated SAR values for the studied samples

	R0	R1	R2	R3	R4	R5	R6	R7	R8
SAR	3.76	5.82	5.80	5.07	4.93	4.63	7.05	7.49	11.42

Table 10: SAR hazard of irrigation water
(http://www.lenntech.com/applications/irrigation/sar/sar-hazard-of-irrigation-water.htm)

Hazard	SAR	Notes	Studied water samples
none	< 3.0	No restriction on the use of recycled water	none
slight to moderate	3.0 – 9.0	From 3 to 6: care should be taken with sensitive crops	R0, R1, R2, R3, R4, R5
		From 6 to 8: gypsum should be used. To be used with insensitive crops	R7
		From 8 to 9: Soils should be sampled and tested every 1 or 2 years to determine whether the water is causing sodium increase	none
acute	> 9.0	Severe damage. Unsuitable	R8

Note: Some studies used Bauder *et al*. (2003) classification, which contains SAR values up to > 26.

Since calcium and magnesium (magnesium hazard MH) in water exceeding (10 meq/l or 200 ppm) (Table 11), the water cannot be used for drinking (Khodapanah *et al*., 2009); therefore, the water sources represented by the water samples R1, R2, R3, R4 can be used for irrigation, while R0, R5, R7and R8 are not suitable for irrigation.

Table 11: Calculated MH values for the studied samples

	R0	R1	R2	R3	R4	R5	R6	R7	R8
MH (ppm)	32.12	10.17	8.02	29.05	33.04	51.27	48.06	42.21	48.30

CONCLUSIONS AND RECOMMENDATIONS

- The T.D.S. of the water sample from the interior of Al-Razzazah Lake found to be (29956 mg/l) which is much higher than that measured by Al-Basrawi (1996) which ranged between 12250 and 13000 mg/l. It has been observed that the lake water near the shore has very low T.D.S. (2917 mg/l) with respect to that from the lake interior, this indicates that this water sample represents the Northern Karbala Drainage water and springs and well water slightly mixed with lake water.
- According to the variable indices used to classify the studied water samples, it has been found that there is contradictory between the Na% and magnesium hardness classifications for samples R0, R5, R7 and R8 (Table 12).

Table 12: Na%, TH, MH and SAR indications for the studied samples

	Na%	TH (ppm)	MH (ppm)	SAR
R0	good	very hard	not suitable for irrigation	care should be taken with sensitive crops
R1	permissible	very hard	can be used for irrigation	care should be taken with sensitive crops
R2	permissible	very hard	can be used for irrigation	care should be taken with sensitive crops
R3	permissible	very hard	can be used for irrigation	care should be taken with sensitive crops
R4	permissible	very hard	can be used for irrigation	care should be taken with sensitive crops
R5	permissible	very hard	not suitable for irrigation	care should be taken with sensitive crops
R7	permissible	very hard	not suitable for irrigation	Gypsum should be used (Insensitive crops)
R8	permissible	very hard	not suitable for irrigation	Severe damage (Unsuitable)

- All the water samples are of $SO_4^{=}$ and Cl^{-} except samples R0 and R6.
- All the water samples R0, R2, R6, R7 and R8 are of Na^+, Ca^{2+} and Mg^{2+} type, while R3 and R4 are of Na^+ and Ca^{2+}, and R5 is of Na^+, Mg^{2+} and Ca^{2+}.
- The hydrochemical facies for R1, R2, R3, R4, R6 and R7 show dominant non carbonate salinity (primary salinity), while R8 shows a dominant non carbonate hardness (secondary salinity) and R0 and R5 show no dominant cation – anion pair.

- The studied water sources could be used for irrigation under certain conditions, except the water sample taken from inside the lake (R8).
- The water of Qattarat Al-Immam Ali is not suitable for drinking.

Generally speaking, poorer quality water (higher salinity and SAR) can be used to irrigate sandy, well-drained soils with good drainage than, can be used to irrigate soils having relatively high clay contents (Bauder *et al*., 2008). Also, most of the studied samples (except R8) could be used to irrigate non-sensitive crops. On the other hand, gypsum could be used with the soils that may irrigate with the water represented by R6 and R7. Caution should be taken when using the water used in sand washing as magnesium concentration is highly increased due to leaching of magnesium from the sand during the washing process.

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