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Evaluation of Gharraf River Water for different Uses, South Iraq

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Abstract

Water quality has become an important requirement in recent years, assumed the enormous pressure on water resources. As a result of the rapid population growth and climate change. Seven sampling stations were chosen along the river, specifically near the important cities. After analyzing the water samples, it was found that pH values range from (7.1 to 7.5). The values of total dissolved ions ranged from (730 to 1390) mg/l. It was found that the sodium percentage in the river water samples ranged from (36.8 to 51.3), which is acceptable for irrigation purposes. The water content of magnesium hazard ranges from (45.1 to 48.6), it is within the permissible limits for watering purposes. The residual sodium amounts range from (-4.01 to -2.86) and are within acceptable limits. Water quality index model was used and according to this model classification, it was found that water is good. PHREEQC model was used to identify the geochemical changes of the river water with distance, found that carbonate mineral were under saturation, while clay mineral were in saturation phase.

Keywords: Gharraf River, quality, SAR, Saturation index

تقييم مياه نهر الغراف للاستخدامات المختلفة، جنوب العراق

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الخلاصة

تعتبر عملية مراقبة والتعرف على نوعية المياه من الضروريات المهمة في السنوات الاخيرة، وذلك نظرا للضغط الهائل عل الموارد المائية، كنتيجة للنمو السكاني الكبير والتغيرات المناخية. حيث تم اختيار سبعة محطات لنمذجة عينات المياه على طول النهر وخلف المدن المهمة. بعد اجراء التحاليل الفيزياوية والكيميائية وجد ان قيم الحامضية تتراوح بين(7.1 الى7.5). بينما وجد ان قيم الايونات الذائبة الكلية تتراوح بين(73 الى 1390) ملغم/لتر. تتراوح نسبة الصوديوم مابين(36.8 الى 51.3) والتي تعتبر ضمن المديات المقبولة. ان محتوى مياه النهر من نسبة المغنيسيوم تتراوح بين(45.1 الى 48.6) والتي تعتبر من ضمن التراكيز المسموح بها لاغراض السقي. بينما وجد ان نسبة الصوديوم المتبقي تتراوح بين(-4.01 الى -2.86) وهي ضمن المديات المسموح بها.تم استخدام موديل نوعية المياه ووجد ان المياه جيدة في كافة المحطات. تم تطبيق موديل فركسي للتعرف على التغيرات الجيوكيميائية خلال المسافة التي يقطعها النهر ووجد ان هنالك عمليات اذابة تحصل للمعادن الكاربونية وعمليات ترسيب لبعض المعادن الطينية.

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1. Introduction

In several arid and semi-arid countries, water is becoming more insufficient resource and enforced planners to suppose any sources of water which might be use cheaply and successfully to encourage further development. The provision of drinking and irrigation water faces major challenges, including the shortage of water and poor quality [1], for the purpose of drinking or irrigating agricultural land to cope with food shortages, as a result of population growth. Surface water are one of the most polluted water sources, because most carrying municipal, industrial, sewage waste as well as the agricultural land drainage channel flows into these rivers [2]. Therefore, the problem requires particular research to evaluate the hydrochemical and mechanical pollution processes to control it. According to spatial and temporal changes in the water quality of the river, the situation requires development of an integrated program to monitor the physic- chemical variables in the important places of the river in order to draw a clear map of the river water quality [3]. The study of trace elements is very important, because it has a significant relationship to pollution. The presence of these elements is related to the geology of the region and the anthropic influence [4]. The river Gharraf is considered one of the important rivers in southern of Iraq, where it runs more than 220 km to reach the marshes in the south. The river feeds communities which settled around it, as well as industrial and agricultural projects.

Through the movement of the river water during these communities, the water of the river is exposed to point and non-point pollution sources, and its water effluence is from these sources. Several studies have indicated that river water is contaminated with some archaeological elements as well as bacterial contamination. Conducting periodic water analyzes gives an opportunity to know the water quality and determine their uses for different purposes.

2. Location and Geology

The study area occupies the areas between Tigris and Euphrates rivers among the provinces of Kut and Dhi-Qar, where the Gharraf River extends between them for 220 km.

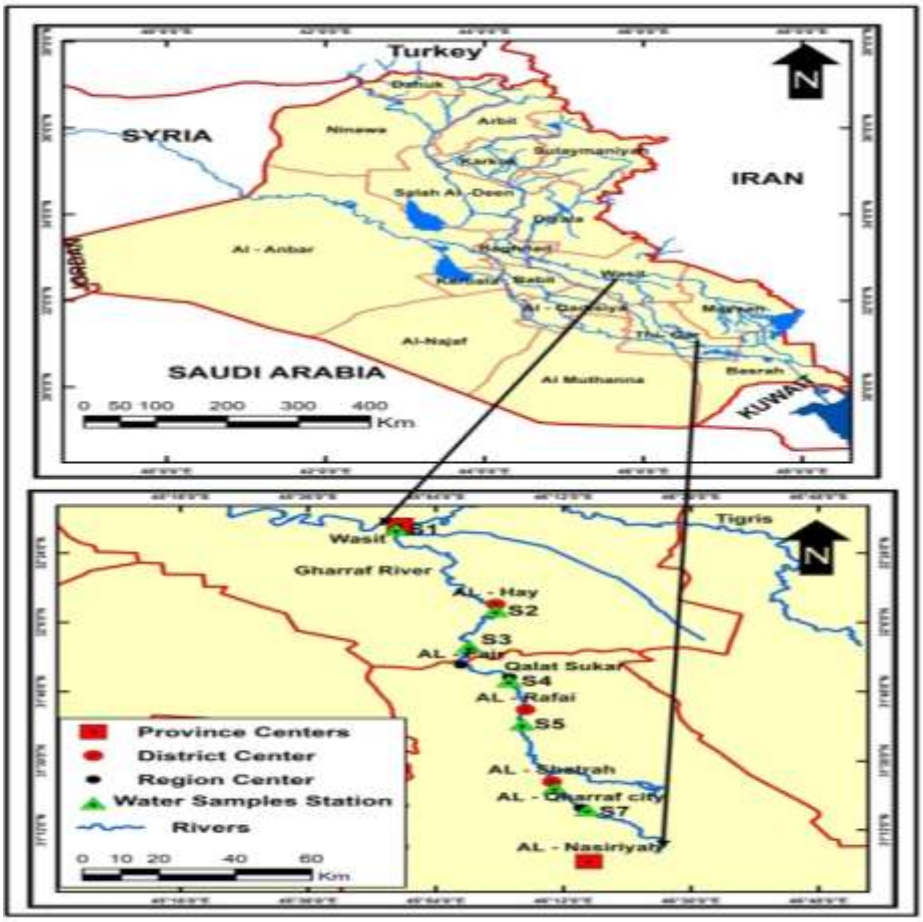

Figure 1-The study area, showing location of the sampling stations

It locates between the Latitude (32°31'21.40" N), Longitude (45°49'17.38"E) and Latitude (31°05'41.60" N), Longitude (46°29'22.05"E). The river is the only fresh water source in the area, and there are no clear and important studies about groundwater (aquifer size, quantity and depth of groundwater) in the area, and only some shallow wells around the river. The Gharraf River extends along a part of Mesopotamia flood plain. The Mesopotamia plain comprises a lake, marsh complex which covered with Quaternary deposit. The thickness of the Quaternary deposit exceeds 250 m. The Quaternary deposit distributed to Pleistocene and Holocene deposits [5]:

2.1- Pleistocene deposits

Pleistocene deposits cover all parts of the study area and the upper limit of this sediment could be up to (1.5 m) below the surface of the ground and up to a thickness of (174 m) and consists of sand, silt, clay inter bedded with each other.

2.2- Holocene deposits

The upper part of the sequence, most of the Holocene period comprises fluviatile flood silts and Aeolian silts. It is alluvial plain deposit which comprises from Rivers Deposit, a deposit of Shallow Depression and Marshes Deposits **.**The Quaternary sediments are unconsolidated and usually finer grained than the underlying formations [5].

3. Material and Methods

During the year 2017, specifically for wet and dry periods nearly fourteen water samples were collected, through seven stations selected near the cities directing the river (Figure-1). The water samples were collected according to Fitter method [6].

For valuation of water quality for human consumption and irrigation the following parameters were studied:

3.1- Sodium percentage and Sodium adsorption ratio

Based on the ratio of sodium in water, water can be classified by Wilcox [7] and Sadashivaiah [8]. This can be calculated by (Eq.1), and that the expression of all the ionic concentrations is in meq / l.

$$\text{Sodium Percentage Ratio} = \frac{\text{Na}}{(\text{Ca+Mg+Na+K})}\ 100 \quad \text{(Eq.1)}$$

SAR can be calculated by the ratio of sodium concentrations to calcium and magnesium concentrations, and through (Eq.2)

$$\text{SAR} = \frac{\text{Na}}{\sqrt{(\text{Ca+Mg})/2}} \quad \text{(Eq.2)}$$

There is a relationship between SAR values in irrigation water and the extent of adsorption of sodium ions [7]. As the high values of the SAR, negatively affect the plant and the physico-chemical properties of the soil and lead to low productivity of the plant as well as the destruction of soil texture [9].

3.2- Magnesium ions hazards

The concentration of Magnesium Ions Hazards is calculated to evaluate the water validity for irrigation purpose. The value of magnesium hazard more than 50, water is as harmful and unsuitable [10]. Magnesium hazard can be calculated using (Eq.3), while the concentration of ions is in meq/l.

$$\text{Magnesium Hazard} = \frac{[\mathbf{Mg2+}]}{[\mathbf{Ca}]+[\mathbf{Mg}]} \times \mathbf{100} \quad \text{(Eq.3)}$$

3.3- Remaining sodium carbonate

An extra of CO3 and HCO3 in water too impacts the quality of water for irrigation purpose. Extreme remaining sodium carbonate (RSC) will decline the soil structure and confine the air and water movement through the soil [11].

Agreeing to the U.S. Salinity Laboratory [12], RSC value <1.25 meq/l is considered 'safe water' for irrigation; The RSC value is proposed by (Eq.4), where ionic concentrations are stated in meq/l

$$\text{RSC} = (HCO^-_3) - (Ca^{2+} + Mg^{2+}) \quad \text{(Eq.4)}$$

3.4- Kellys Ratio

Kelly's ratio (KR) can be calculated by (Eq.5) and the concentration of ions is in meq/l [13].

$$\text{KR} = \frac{\text{Na ion}}{(\text{Ca+Mg})\text{IONS}} \quad \text{(Eq.5)}$$

3.5- Permeability Index

Doneen [14] suggests an equation to assess the validity of irrigation water established on a permeability index (PI). The PI value is calculated by (Eq.6) and the concentration of ions is in meq/l:

$$PI = \frac{Na + \sqrt{HCO3}}{Ca + Mg + Na} \text{ ----- (Eq.6)}$$

Where PI is used to assess sodium risk on irrigation water, and, therefore, specify its appropriateness for irrigation purposes. Water can be classified into three orders, Class I and Class II waters are categorized as 'good' for irrigation purposes, with 75% or more of permeability, whereas Class III waters are 'unsuitable' for irrigation purposes, with only 25% of maximum permeability.

3.6- Water Quality Index

Water Quality Index has been developed by Brown et al [15] and by Cude [16], which relied on weights for the separate quality parameter. The Water Quality Index is a powerful tool to provide a comprehensive and clear picture of the qualitative variables and the validity of water, whether groundwater or surface water alike [17]. It is calculated as follows:

The specific weight of variable water parameters are different between each other according to the importance of these variable and its health effect (wi) which were developed on a scale starting with 1 to 5. The highest weight of 5 is assigned to parameters that have critical health effects and whose presence above the critical concentration limits can limit the water usability of the household and drinking purposes and is for (NO_3^{-1}) ions. The minimum weight of 1 was set to K-ions due to its insignificant effect on water quality. Other quality parameters such as pH, EC, TSS, HCO_3^-, Cl^-,SO_4^{-2}, , Ca^{+2}, Mg^{+2}, were assigned weights between 2 and 4 built on their qualified significance in the water quality assessment. The virtual weight (w_i) is calculated by (Eq.7):

$$Wi = wi / \sum_{i=1}^{a} wi \text{ ----- (Eq.7)}$$

Where:

W_i = is the relative weight

w_i = weight of each parameter.

n = number of parameters

The calculated of relative weight (wi) values of each parameter are specified in (Table-1).

The quality rating (qi) for each parameter is assigned by dividing its concentration in each water sample by its limit values given by the (WHO) [18], and the result multiplied by 100.

$$q_i = (C_i / S_i) \text{ X } 100 \text{ ----- (Eq.8)}$$

Where:

q_i = the quality ranking

C_i = the concentration of every chemical parameter in every one water samples in mg/l

S_i = the drinking water standard for each chemical parameter (mg/l) according to the guidelines of the WHO [18]

To compute WQI, SI rate should be determined by the next equations:

$$SI = Wi \text{ X } qi \text{ ----- (Eq.9)}$$

$$WQI = \sum_{I=1}^{n} SIi \text{ ----- (Eq.10)}$$

Where:

SI_i = the sub index of thirteen parameter.

Qi = the quality rating based on concentration of thirteen parameter.

Table 1-Relative weight of chemical parameters

Parameters	Unit	WHO standard (2011)	Weight (w_i)	Relative weight(Wi)
pH		6.5-8.5	4	0.125
EC	S/cmμ	1400	4	0.125
TSS	mg/l	25-40	2	0.0625
Na^+	mg/l	200	2	0.0625
K^+	mg/l	12	1	0.03125
Mg^{2+}	mg/l	125	2	0.0625
Ca^{2+}	mg/l	75	2	0.0625
Cl^-	mg/l	250	3	0.09375

NO^-_3	mg/l	50	5	0.15625
SO^{2-}_4	mg/l	250	4	0.125
HCO^-_3	mg/l	125 - 130	3	0.09375
			Σ 32	Σ 1

3.7. Saturation index

The properties of the PHREEQC MODEL were used to identify the geochemical changes along the course of the river through the saturation index, concluded which minerals that precipitates and those which dissolve. The model was applied on surface water for the same purpose by Elahe and Mohsen [19] and Ying [20].

4. Results and discussion

The hydrochemical variables were studied as well as heavy elements included in Tables- (2, 3, 4). The values of the water constituents are explained in ppm expect EC in µS/cm.

Table 2- Hydrochemical parameters of Gharraf River water (Wet period)

Station	pH	EC	TDS	Ca^{2+}	Mg^{2+}	Na^+	K^+	Cl^-	HCO_3^-	SO_4^{2-}	NO_3^-
S1	7.3	937	680	56	28	124	2	162	66	234	1.1
S2	7.11	965	724	61	33	130	5	172	69	244	2
S3	7.5	1200	766	90	35	100	2.8	125	90	320	2
S4	7.15	1014	814	78	45	146	11.2	205	79	278	2.3
S5	7.3	950	681	56	28	125	2	161	66	233	1.1
S6	7.1	1074	833	74.8	43	151	8	198	80	280	1.5
S7	7.16	982	780	72	41	141	8	192	79	270	1.2

Table 3- Hydrochemical parameters of Gharraf River water (Dry period)

Station	pH	EC	TDS	Ca^{2+}	Mg^{2+}	Na^+	K^+	Cl^-	HCO_3^-	SO_4^{2-}	NO_3^-
S1	7.13	1096	753	64	33	138	6	177	70	247	1.1
S2	7.12	900	730	64	38	116	9.6	188	60	250	1.5
S3	7.1	1000	972	57	28.5	123	4.5	160	63.5	222.9	1.2
S4	7.1	1158	979	85.6	51	158	14	246	79.5	328	1.4
S5	7.2	1163	983	86	52	159	14.3	248	79.8	329.7	1.4
S6	7.13	1196	993	87	52	164	16	250	80	335	1.2
S7	7.12	1552	1390	110	80	193	23	337	95	480	1.2

Table 4-Trace element concentration in water samples through wet and dry periods (µgm/l)

	Wet period					Dry period				
Stations	Pb (ppm)	Cd (ppm)	Cr (ppm)	Cu (ppm)	Zn (ppm)	Pb (ppm)	Cd (ppm)	Cr (ppm)	Cu (ppm)	Zn (ppm)
S1	0.012	0.025	0.004	0.06	0.057	0.0134	0.029	0.043	0.084	0.0816
S2	0.016	0.036	0.055	0.0779	0.0884	0.081	0.026	0.04	0.084	0.0805
S3	0.081	0.041	0.058	0.084	0.0884	0.0107	0.0658	0.013	0.0717	0.066
S4	0.032	0.072	0.051	0.0779	0.122	0.054	0.0557	0.038	0.087	0.069
S5	0.021	0.021	0.069	0.093	0.095	0.0107	0.0678	0.038	0.0498	0.068
S6	0.0242	0.048	0.0119	0.0748	0.077	0.027	0.0484	0.046	0.0872	0.0794
S7	0.095	0.024	0.064	0.0936	0.0986	0.027	0.0581	0.085	0.0717	0.0669

4.1. Water suitability according to global and local determinant

The minimum, maximum and average physic-chemical parameters of Stations (S1through S7) were cited in Table-5 for comparative with/and according to Langmuir [21], the mean results of analyzes for the seventh stations were compared with what Langmuir put it from determinants. It was found that the pH rate, TDS, major ions and trace elements such as Pb, Cd, and Zn exceeded those determinants of natural water for the two periods, while Cr and Fe are in the permissible limit [22]. The main source of these trace elements is often the sewage and industrial waste of cities.

There are several standards defining the suitability of water for drinking such as WHO [23] and Iraqi standards [24]. According to these two standards, all surface water in the study area for the two periods were suitable for drinking purpose Tables-(6, 8), TDS is in permissible limits, except in station S7 (Downriver) for the Gharraf River (wet and dry), it was exceeded the permissible limit.

Table 5-he maximum, minimum and average physic-chemical parameters of the Gharraf River (S1 through S7) with Langmuir mean [21].

Para.	Unit	Min.	Max.	Mean	Mean*
pH	-	7	7.2	7.12	ND
EC	µS/cm	900	1552	1152	ND
TDS	mg/l	730	1390	971	120
Ca^{2+}	ppm	57	110	79	15
Mg^{2+}	ppm	28.5	80	47.7	41
Na^{+}	ppm	123	193	150	63
K^{+}	ppm	4.5	23	12	23
HCO_3^-	ppm	60	95	75	58.4
Cl^-	ppm	160	377	229	7.8
SO_4^{2-}	ppm	222.9	480	313	11.2
NO_3^-	ppm	1.1	1.5	1.2	1
TH	ppm	259	603	394	ND
Pb	ppm	0.012	0.0134	0.012	0.003
Cd	ppm	0.025	0.029	0.027	0.001
Cr	ppm	0.0041	0.0043	0.0042	0.0064
Cu	ppm	0.060	0.0841	0.072	0.003
Zn	ppm	0.057	0.0816	0.069	0.020
Fe	ppm	0.012	ND		0.100

*** (Mean of natural water worldwide (After Langmuir [21]), ND= Not detected.)**

According to Him [25], all the water samples studied were occupied with fresh water categories except Station 7 through March which reach to 1340 mg/l and occupied slightly saline water (Table-6), as a result of sewage water discharges into the river directly without treatment.

Table 6-Classification of the Gharraf River water according to total dissolved solid (TDS) after Him [25].

Water type	TDS	Surface water
Very fresh	< 300	-
Fresh	300-1000	S1,S2,S3,S4,S5,S6
Slightly Saline	1000-3000	S7 (Only S7)
Moderately saline	3000-10000	-
Very saline	10000-35000	-
Brine	>35000	-

Total hardness range between (259 to 603 mg/l) for the two periods. Most of the samples are considered hard to very hard and the high concentrations of hardness are due to the discharge of sewage into the river especially in S7 (Table-7).

Table 7-Classification of Gharraf River water samples according to their Total Hardness concentration, after Boyd [26].

Water type	TH(mg/l)	Surface water
Soft	< 50	(259-603)
Medium hard	50-150	
Hard	150-300	
Very hard	>300	

Table 8-Gharraf River Water Samples comparing with WHO [27]and IQS,[24] standards for Drinking Water Suitability

Parameter	IQS 2009	WHO 2007	Wet	Dry	Exceeding limits
TDS	1000	1000	833	1390	Exceed only in S7
PH	6.5-8.5	6.5-8.5	7.5	7.2	Not exceed
TH	500	500	379.7	641.3	Exceed in S7
Ca	150	75	90	110	Exceed in S7
Mg	100	125	45	80	Not exceed
Na	200	200	151	193	Not exceed
K	-	12	11.2	23	Exceed in S7
Cl	350	250	205	337	Not Exceed
SO_4	400	250	320	480	Exceed in S7
NO_3	50	50	2.3	1.5	Not exceed

The Gharraf Water had been evaluated for livestock uses depending on the classification proposed by Altoviski [28][29]. This classification is based on some of the major cations and anions as shown in Table-(2, 3). According to Altoviski [28] classification, all the water samples from Gharraf River were very good for livestock uses (Table-9).

Table 9-Specifications of waters for livestock consumption purposes

Element	Very good water(ppm)	Good water(ppm)	Permi(ppm)	Can be use	Threshold
Na	800	1500	2000	2500	4000
Ca	350	700	800	900	1000
Mg	150	350	500	600	700
Cl	900	2000	3000	4000	6000
SO_4	1000	2500	3000	4000	6000
TDS	3000	5000	7000	10000	15000
TH	1500	3200	4000	4700	54000

The suitability of water samples for building purposes is based on Altoviski [26] classification; all water samples of the Gharraf River are suitable for building purposes (Table-10).

Table 10-Water quality Guide for Building Uses [28]

Parameters	Na^+	Ca^{+2}	Mg^{+2}	Cl-	SO^{-2}_4	HCO^-_3
Permissible limit	1160	437	271	2187	1460	150

4.2. Sodium Percentage

Based on the ratio of sodium in water, water can be classified as "excellent" (<2%); "good" (2-40%); permit (40-60%); Doubtful" (60-80%); "inappropriate" (> 80%) [7 and 8].

The sodium percentage in river water samples is ranged (36.8 to51.3) Tables-(2, 3). It is clear that the sodium percentage fall within the range of (40 to 60). This range is permissible.

Richard [9] classified the irrigation water according to its content of SAR to the following categories:

1. Good water (SAR up to 10)
2. Moderate water SAR ranges between (10 to 18)
3. Intermediate water SAR ranges between (18 to 26)
3. Unsuitable water (SAR more than 26)

The concentration of SAR for the two periods is ranged between 2.79 to 5.49. According to Richard [9] classification, all water samples regarded good water for irrigation purposes.

4.3. Magnesium Hazard

The concentration of Magnesium Ions Hazards is calculated to evaluate the water validity for irrigation purpose. The value of magnesium hazard more than 50, water is as harmful and unsuitable [10].

Gharraf River water is nearly out of the range of Magnesium Hazard, which was ranged between (45.1 to 48.6) for two periods <50 percent. So, it is suitable for irrigation purpose Tables-(2, 3). But they are worthy of attention, because the magnesium ion concentration is close to the critical limit of the ratio which form a significant risk on soil and plant especially at Shatrah and Gharraf Districts.

4.4. Residual Sodium Carbonate

An extra of CO3 and HCO3 in water too impacts the quality of water for irrigation purpose. Extreme remaining sodium carbonate (RSC) will decline the soil structure and confine the air and water movement through the soil [11]. Agreeing to the U.S. Salinity Laboratory [12], RSC value <1.25 meq/l is considered 'safe' for irrigation; The RSC value is proposed as below, where ionic concentrations are stated in meq/l.

Table 11-RSC for Gharraf River water samples

Station	RSC meq/l (Wet Period)	RSC meq/l (Dry Period)
S1	**-4.01**	**-2.869**
S2	**-4.63**	**-3.349**
S3	**-5.89**	**-3.773**
S4	**-6.29**	**-4.15**
S5	**-4.01**	**-4.36**
S6	**-5.96**	**-4.51**
S7	**-5.66**	**-5.01**

The RSC value in Gharraf water samples varied from (-5.01 to -2.869) meq/L during the dry period and (-6.29 to -4.01) meq/L during the wet period (Table 11). U.S. Salinity Laboratory [12] specified that an RSC value is <1.25 meq/L is considered safe for irrigation; a value between 1.25 and 2.50 meq/L is of moderate quality and a value >2.50 meq/L is unsuitable for irrigation. Approximately 100% of the samples show negative values, which indicated that dissolved Ca^{2+} and Mg^{2+} concentrations were higher than HCO3- content. However, with respect to the RSC value, all samples are safe for irrigation purposes where the RSC values were less than 1 meq/L Tables-(2, 3, 11).

4.5. Kelly's Ratio

The Kelly's ratio of 1 or <1 indicates good quality of water for irrigation. If the Kelly's ratio is > 1, the water is not suitable for agricultural purposes due to the extra level of Na^+ in the water [13].

The Kelly's ratio is around 1 during the dry period and 0.5 to 1 during the wet period Tables-(2, 3 and 12). The Kelly's ratio, which is greater than 1 specified that water is inappropriate for agricultural purposes due to the extra level of Na^+ in the water [13]. It is observed that almost 100% of the samples were equal to 1 for the dry period and less than 1 or equal to 1 in the wet period (Table-12). The results suggest that 100% of the stations, especially from S1 to S2 were regarded as good quality for irrigation purposes.

The Kelly's Ratio is in the permissible limit with ranged from (0.5 to 1.0) for the two periods Tables-(2, 3, 12). These results lead to that, the water of the river Gharraf at the current discharge, is in a critical position and any decrease in the discharge of the river may lead to the rise of sodium ions concentrations, thus the water becomes unsuitable for irrigations purposes (Table-12).

Table 12-Kelly's Ratio for Gharraf River

Station	KR meq/l (wet Period)	KR meq/l (dry Period)
S1	1	1
S2	0.9	1
S3	0.5	1
S4	0.8	1
S5	1.	1
S6	0.9	1
S7	0.8	1

4.6. Permeability Index

Doneen [14] suggests an equation to assess the validity of irrigation water established on a permeability index (PI). Where PI is used to assess sodium risk on irrigation water, and, therefore, specify its appropriateness for irrigation purposes. Water can be classified into three orders. Class I and Class II, waters are categorized as 'good' for irrigation purposes, with 75% or more of permeability, whereas Class III waters are 'unsuitable' for irrigation purposes, with only 25% of maximum permeability.

Table 13-Permeability Index (PI) Ratio for Gharraf River

Station	Σ Ions(epm) Wet	PI % (Wet)	Σ Ion(epm) Dry	PI % (Dry)
S1	21	61.3	25	62.5
S2	22.6	58.8	23.1	61.6
S3	22.8	47.4	30.8	61.1
S4	25.8	53.7	30.8	60.5
S5	21.1	61.4	31.1	60.2
S6	26.7	55.7	31.5	60
S7	26.6	55.5	42.1	58.8

Through using Doneen diagram, it was found that the Gharraf River water were in the first class of the diagram. This means that water is good for watering purposes Tables -(2, 3, 13), and Figure-2. All samples were categorized in low class indicating low sodium and bicarbonate. These classes indicate low to moderate salinity water. It can be used for irrigation [14].

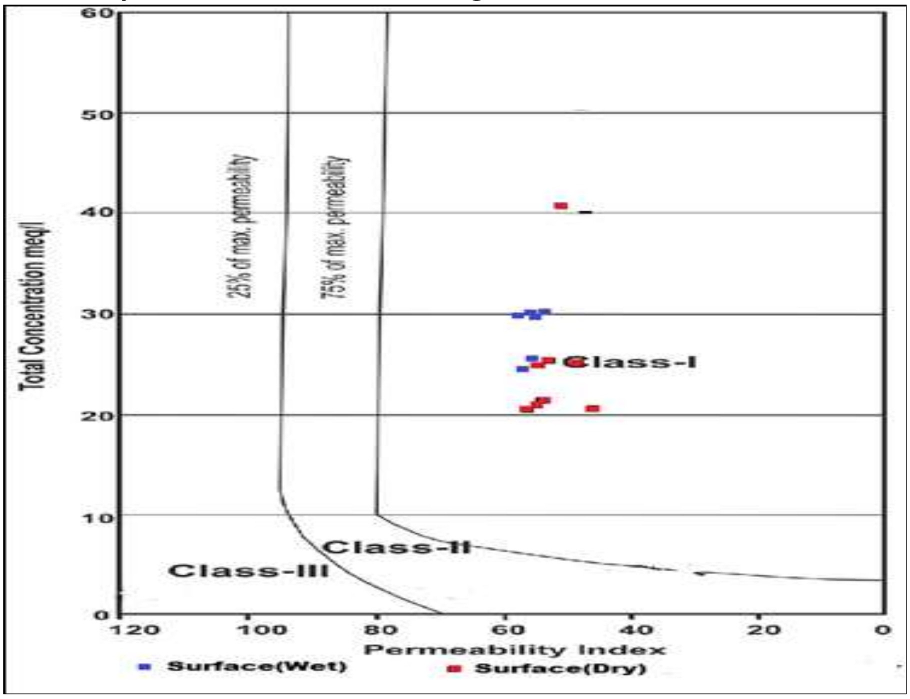

Figure 2-Doneen Diagram for validity of irrigation water.

4.7. Water Quality index

To evaluate WQI of the river, pH, EC, TSS, HCO_3^-, Cl^-, SO_4^{2-} , Na^+, Ca^{2+}, Mg^{2+}, and $NO3^-$ were employed for calculation of Water Quality Index (Table-14).

Table 14-Water Quality Index for Gharraf River (Wet and Dry Periods)

Station No.	Wet Period	Dry Period
	WQI	WQI
S1	63.435	64.94
S2	56.185	67.13
S3	62.206	60.28
S4	62.206	70.6
S5	60.896	61.8
S6	68.272	68.51
S7	69.658	71.54

Table 15-The WQI categories [16]

Range	Quality
< 50	excellent water
50-100	Good water
100-200	Poor water
200-300	Very poor
> 300	Unsuitable for drinking

The calculated values of WQI for the seven stations through wet and dry periods are between (56.185 to71.54) (Figure-3). The spatial variation of WQI suggested that low significant decrease of the water quality index from upstream to downstream. According to the WQI (Table-15), all the River water is good (Table-14).

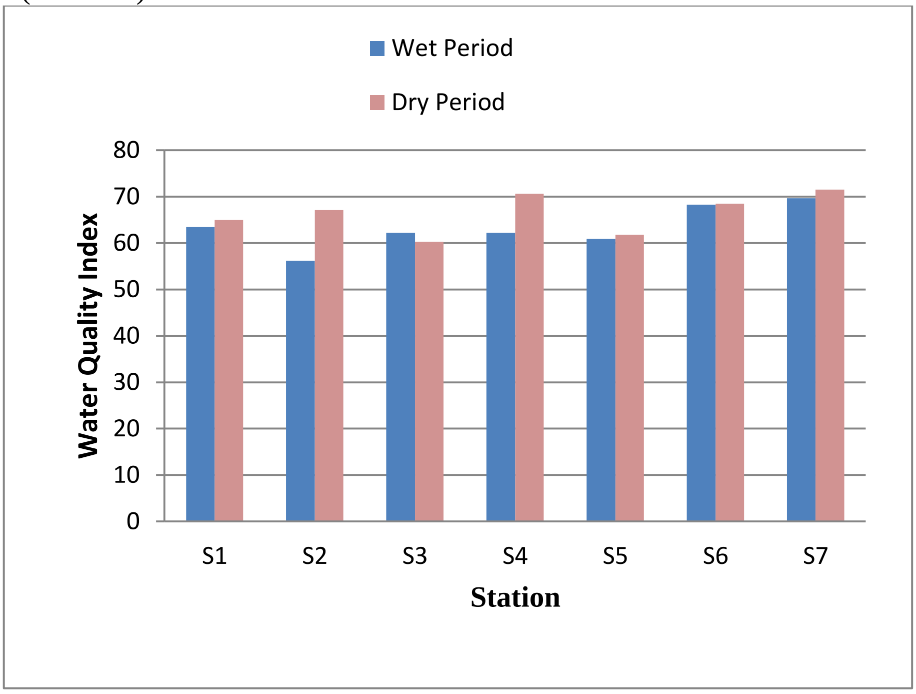

Figure 3-Water quality index of Gharraf River (Wet and Dry periods)

4.8. Saturation Index and dissolution

The saturation index is used to verify the presence of different phases of minerals in the surface water [30]. Whether those in the case of dissolved or precipitated and absorbed. The result through Table-16 and Figure-4 shows that all river samples are under saturation for some carbonated minerals (Calcite, Dolomite, and Aragonite) and non-carbonate such as albite and K-Feldspar.

This indicates that the water of the river is capable of dissolving other quantities of these minerals if they exist abundantly in the river basin which was flowing, or this condition indicates that these minerals are not available in the river basin.

Table 16-Saturation Index for Calcite, Dolomite , Aragonite, Albite, and K.feldspar

	Si;Calcite	Si;Dolomite	Si;Aragonite	Si;Albite	Si;K-feldspar
S1	-0.9309	-1.9743	-1.0829	-2.584	-1.563
S2	-0.4214	-0.9539	-0.5734	-2.328	-1.294
S3	-0.3245	-0.7601	-0.4765	-3.022	-1.987
S4	-1.0549	-2.2211	-1.2069	-3.215	-2.177
S5	-1.0114	-2.134	-1.1634	-2.043	-0.999
S6	-0.9875	-2.0863	-1.1395	-3.599	-2.5513
S7	-0.9413	-1.9681	-1.0933	-4.679	-3.455

(Si=Saturation index)

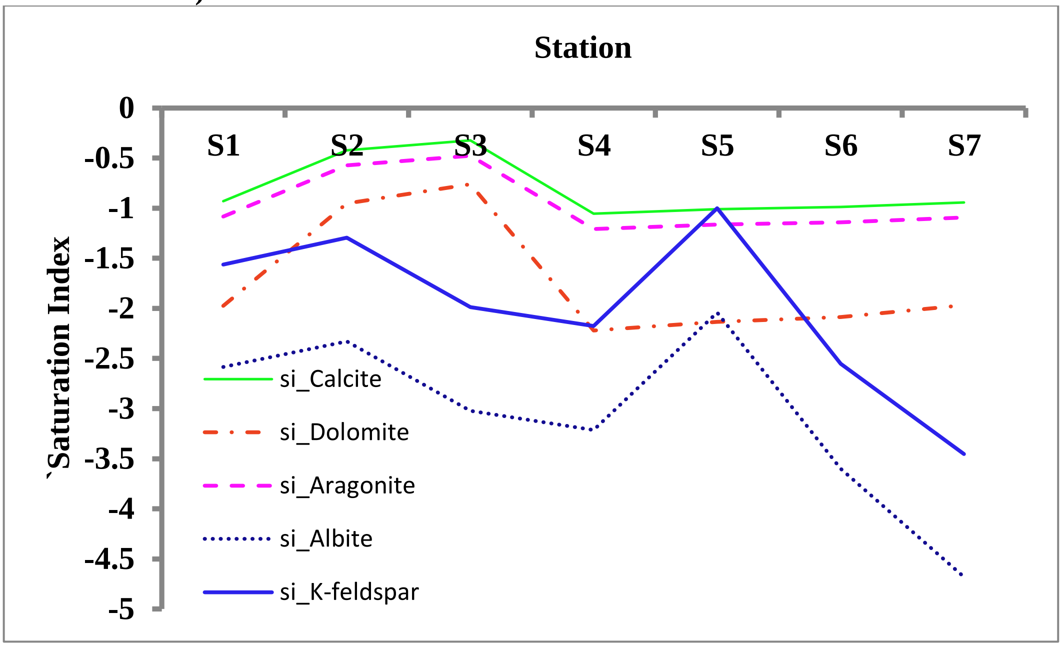

Figure 4-Saturation Index for Calcite, Dolomite, Aragonite, Albite and K.feldspar.

On the other hand, it is clear that the saturation index of clay minerals is positive for kaolinite, Montmorillonite and illite (Table-17). And it's in a super saturation and precipitation state phase. While the SI of the chlorite mineral is negative, this is close to saturation phase and is in a state of dissolution (Figure-5).

Table 17- Saturation Index for clay minerals

Station	Si;Kaolinite	Si;Chlorite	Si;Illite	Si;Ca-Montmorillonite
S1	3.3159	-6.6057	0.3475	1.1042
S2	2.522	-3.0437	0.0471	0.4468
S3	1.9154	-3.6544	-0.8735	-0.5497
S4	3.3633	-10.1417	-0.1493	0.7762
S5	5.3286	-7.9132	2.2372	3.178
S6	4.2817	-9.4284	0.4188	1.2596
S7	2.2515	-11.1736	-1.8328	-1.1671

(Si=Saturation index)

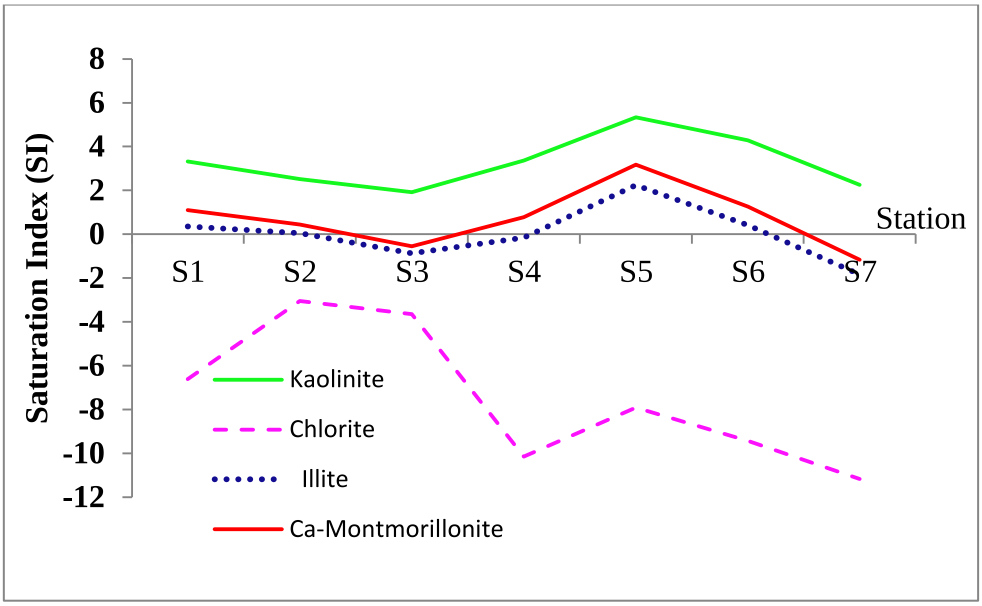

Figure 5-Saturation index of clay minerals

5. Conclusion

Gharraf River is considered one of the most important rivers in Iraq. Where it is considered the main source of fresh water for the area between the provinces of Kut and Dhi-Qar. According to WHO and Iraqi standards, the river's water are suitable for human use, except for S7 station, where there is a rise in the values of total dissolved solids. This is as a result of the accumulation of sewage, industrial waste, fertilizers and agricultural pesticides, which are dumped directly to the river without treatment. The water of the river is suitable for watering purposes under current water discharge. But found that the Na and Mg ions concentrations have been found to be close to threatening water quality for irrigation purposes. Through the saturation index, it was found that there was a phase of dissolving of the carbonate minerals and precipitation phase of clay minerals. It therefore requires monitoring water quality and river discharge continuously.

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